November/December 2007

VOLUME 21 ISSUE 2

TEACHERS' INNOVATIONS IN K–8 SCIENCE, MATH, AND TECHNOLOGY

Connect™

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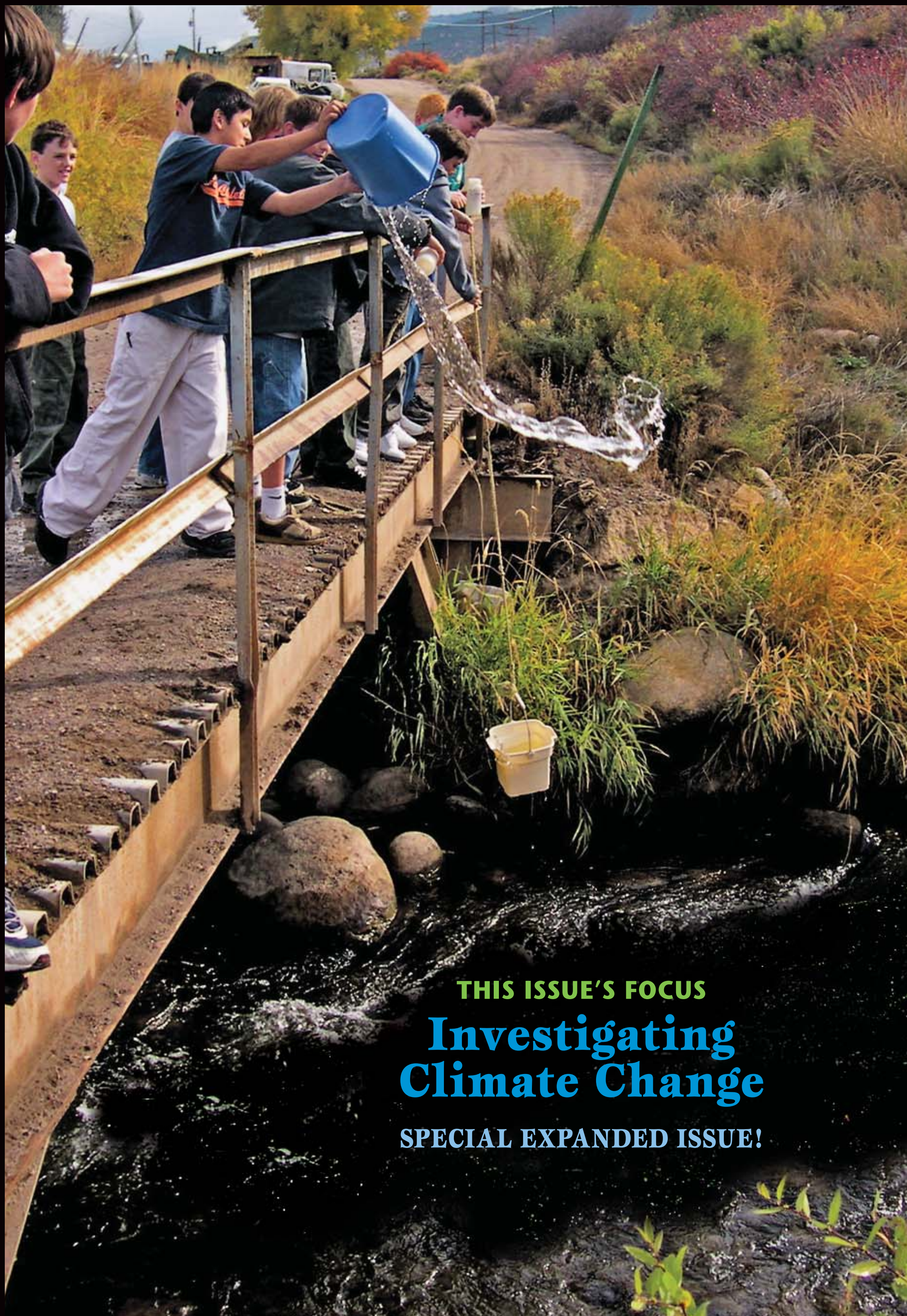

THIS ISSUE'S FOCUS

Investigating Climate Change

SPECIAL EXPANDED ISSUE!

Investigating Climate Change

Whether we can specifically target the cause(s) of climate change, or the best course of action to take to amend it, the most basic and lasting thing we can do for our students is to give them the tools they will need to navigate these next several decades. We can help them to notice change, to develop ideas and questions based on data, and to participate in their communities with confidence and respect. Today's students will witness dramatic changes in their lifetimes. Many will effect change not only as individuals, but eventually as policy makers, business people, developers, and stewards of our environment.

How many of us understand direct effects of climate change on our everyday lives?

In tropical and arctic climates, residents know all too well the changes that come about, as Ken Stenek writes in his lead article. His Alaskan students live the issue of climate change on a daily basis.

There's rich ground here for teachers to explore the science, technology, and math of climate studies, but also great potential for inundating our students with knowledge they cannot effectively apply. Too much information at the wrong time may prove counterproductive, as David Sobel explains in his article investigating helpful ways to involve children.

One effective way is to track observable changes over time such as in tulip plants, as students participating in Journey North do in Holly Cerullo's article. Julie Casper writes of the technology that's available on the Internet for tracking weather data in local, then global regions. Paulina Essunger describes her challenge to provide a meaningful presentation based on *An Inconvenient Truth* to fifth graders. Ted James relates the actions of his seventh and eighth graders participating in River Watch, as they take on the revitalization of an endangered species in their local river. Pictured here, they are learning about their world and changing it at the same time.

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Global Climate Change

What to Teach and When?

by Ken Stenek

It is an awesome responsibility to teach science at any level in this day and age. As the science teacher for grades seven through twelve at Shishmaref School, that responsibility is humbling.

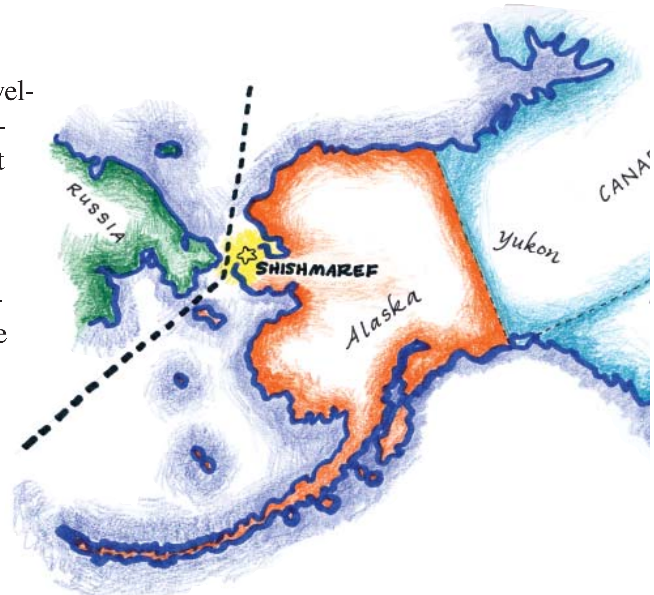
Shishmaref is located on Sarichef Island on the northern coast of the Seward Peninsula in Northwest Alaska. A village of 650, there are approximately 185 students (K–12), sixteen certified teachers and two administrators. Shishmaref is one of fifteen sites within the Bering Strait School District (BSSD).

Shishmaref, Alaska, is often referred to as the "poster child" of global warming. The community is directly affected by coastal erosion along the Arctic coast, which is similarly related to sea ice forming later than usual in the year, and melting permafrost. Because of these conditions, the community has voted to relocate to a safer location nearby and is awaiting Federal and State funding to facilitate that move.

Recently, worldwide media have inundated Shishmaref in an attempt to give a face to climate change. Reporters constantly ask our students questions about climate change as if they were experts on the topic. The students here are not developmentally different from their counterparts in public schools throughout the United States except for the obvious geographical and cultural experiences. This has often led me to the big question, what do you teach a student and when?

Standards-based curriculum

The Bering Strait School District is one of several school districts in the state of Alaska that uses a standards-based instructional model. The District has adopted standards in nine content areas. Each content area has incremental levels within which are developmentally appropriate standards for that level.



Students are not evaluated using a traditional A-F grading scale or Carnegie units for graduation. Students must show proficiency on each standard and complete an End-of-Level Assessment (EOL) to move to the next level.

Progress reports show what levels students are in and what standards have been mastered or have been introduced for each content area. Because students work at different ability levels, multi-age or multi-level classrooms are the norm.

Teachers must also be mindful of the things that students will be required to know for the Alaska state tests (SBAs). The Department of Education and Early Development have published Grade Level Expectations (GLEs) that are minimums of what a student should know in each grade. Thankfully, our District's standards and the State's GLEs align very well.

Here is the problem that science teachers have to overcome no matter where we teach: With many administrators pushing to do better on standardized tests to make adequate yearly progress for NCLB, how do we find the time to teach students about global warming when mastery of that topic is not an expectation for their state assessments? Are we doing students or the school a disservice by teaching them things that they do not need in order to pass their tests or meet graduation requirements?

As the warming climate thaws the permafrost, structures built on once solid (frozen) ground are collapsing.

Real-world connections

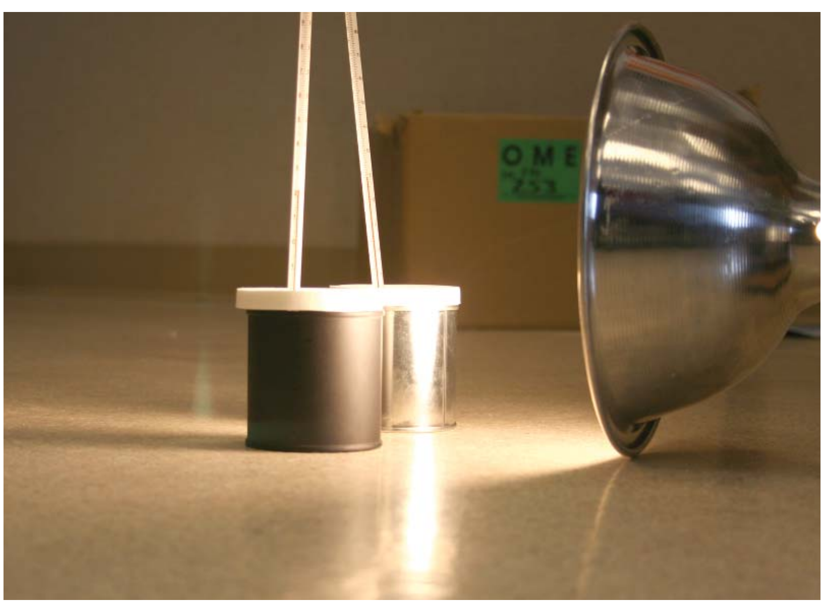
We are not limited to teaching our students the *minimum* for their developmental level. For example, how do we teach conservation of energy? We define energy, discuss the different forms of energy, and the transformation of energy from one form into another, etc. We might get out a flashlight and ask students what forms of energy are present in the system (chemical, electric, light, and heat). As a result, students may have a minimal understanding about how energy is conserved and that energy can be transformed and/or transmitted.

Take the concept a little bit farther and have students heat up two metal cans—one painted black and the other left shiny silver—with a heat lamp. Students learn that the black can heats up faster. Then have the students heat a bowl of soil and a bowl of water with a heat lamp. Students learn that the dark soil absorbs more energy than the water. In doing this, have the students learned about the conservation of energy? Have they learned a little about how the conservation of energy relates to Earth systems?

How does this relate to climate change? Climatologists study the *albedo* (ratio between the amount of total incoming light and the amount reflected) of a variety of Earth surfaces. Darker surfaces absorb more light and lighter surfaces reflect more light. So a darker surface has a lower albedo than a lighter surface. This is seen around water where the land will absorb more light than the water will. However in the Arctic, where there is sea ice, the sea ice reflects more light than the water. As the summer extent of sea ice decreases, the water can absorb more energy, increasing ocean temperatures in the Arctic. Students now have a real-world connection between the conservation of energy and climate change.

Well that's great for physical science or earth science, but I also teach life science. I was teaching students about limiting factors of populations. As we discussed how limiting factors keep species' numbers in equilibrium, and I showed examples of graphs, etc., I gave students a local example of how predation limits arctic hare numbers. Students might have a proficient understanding about populations and limiting factors. So why not take it a step further and discuss how spruce bark beetles in southeast and south central Alaska are devastating the spruce forests in those regions? Temperatures have increased the most in Alaska during the winter; therefore winters have become shorter. This has allowed spruce bark beetles more time to spread through the

Students observe differences while heating a black can and a reflective can.



summer months. Students have another real-world connection between populations and climate change.

What is developmentally appropriate?

As the father of two students in primary grades, I understand that many concepts relating to climate change may not be appropriate for them. At the same time I have gone on record as saying that, "I don't believe there's an age that they're (students) too young to study climate change." (Lempinen, 2006) The media has bombarded our youth with movies, images, and news stories about climate change.

We have at our disposal a great resource that gives us an idea of what concepts are developmentally appropriate in the form of the *Atlas of Science Literacy*, volumes I and II, produced from Project 2061 at AAAS (the American Association for the Advancement of Science). Many teachers may have either or both of these very important resources and if not they would be a good investment. These are large books that cover many science education concepts regarding what should be introduced at what ages.

AAAS has produced an abbreviated guide just for climate change titled *Communicating and Learning about Global Climate Change* that can be downloaded in PDF form from the AAAS Web site http://www.aaas.org. This guide takes science concept pages from both volumes I and II of the *Atlas of Science Literacy* relating directly to climate change and groups them together for easier use.

Thinking back to the concept of energy transformation, the *Atlas of Science Literacy* believes students in primary grades (K–2) should understand that "the sun warms the land, air, and water." You can do a demonstration of this with a heat lamp, by heating some soil and water in a bowl, and air in a sealed flask, and have students observe the temperature over time. How do they heat differently? Does the heating behave differently if you add some water to the soil and to the air in the flask?

In the elementary grades (3–5) students should understand that "when liquid water disappears, it turns into a gas (vapor) in the air and can reappear as a liquid when cooled. . . ." If you put some water in a sealed flask, what happens to the temperature of the air if you heat the flask with a heat lamp over time? What happens to the amount of water in the bottom of the flask? What happens if you put the flask in a refrigerator and cool it quickly? These are important concepts relating to climate change and have differences of importance depending on where you teach regionally because of your local climate.

The Atlas of Science Literacy, Volumes 1 and 2
($99.95, or $55.95 each), are available from AAAS. Call 888-737-2061, online at: http://www.project2061.org.

Water in its gaseous state is not only important to life for photosynthesis and respiration, but it is also the most important greenhouse gas and without it temperatures on Earth would not sustain life. The greenhouse effect is one of the greatest attributes of the Earth's atmosphere. But as humans continue to burn fossil fuels and release more greenhouse gases into the atmosphere, temperatures will rise to a point where species, including humans, will be forced to adapt to new environments or become extinct.

It is doubtful that scientists will agree upon the causes of global warming; the Earth system is just too complex. I believe that as educators we must teach the concepts relating to climate change to students so that they may be more informed and able to separate truth from conjecture. I do not believe that climate

These traditional drying racks are a symbol of a way of life that will be lost as the Arctic climate warms.

Ken Stenek has taught science to seventh through twelfth grades at Shishmaref School since 1999. Located in the Inupiat Eskimo village of Shishmaref, Alaska, the school has 185 K–12 students. Ken grew up in Western Washington in a small rural community before moving to Alaska to attend the University of Alaska Fairbanks.

change is an "adult problem" as much as it is a human problem. And although our youth have not created the problem they are the future and they can effect change presently.

It is not our role as educators to spread our political agendas or create panic for our students. It's true that over time humans have played a role in climate change through our release of greenhouse gases and other means. But what can students think of to help decrease our role in climate change? I believe that our youths' imaginations are only limited by our willingness to deny or support their ideas. And to give them a "canvas" to find solutions may be one of the greatest gifts we can give to students as we teach them the concepts of global warming. ✐

Resources

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Roseman, Jo Ellen. "Communicating and Learning about Global Climate Change." AAAS, 2007. http://www.aaas.org/news/press_room/climate_change/mtg_200702/climate_change_guide_2061.pdf.

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Tulip Garden

by Holly Cerullo

Ah, the mind of the seventh grader! No matter how carefully I choose my words, no matter how diligently I try to be concise in my introduction to a topic, my students always seem to oversimplify. One of my students had the concept that somehow, a tulip was going to miraculously explain changes in our climate. Well, maybe he wasn't as far off as it would appear at first glance.

Even though it is a pretty big leap from planting a tulip bulb to observing world climate, it is this small bulb that captures the students' interest and holds that interest long enough to collect data and make factual observations about seasonal changes. From those observations of seasons within their own geographic areas, students then transition to comparing observations around the world. The sometimes difficult and controversial topic of our changing climate can be an overwhelming topic for the middle school student. But, by starting with this concrete activity of planting tulips, students have observable, measurable data to connect them to the bigger picture.

Journey North (http://www.learner.org/jnorth), a free, Web-based science program that provides sets of investigations that encourage students to explore the concept of seasonal changes, is what I have found to be the perfect project to introduce the topic of global climate changes. In this activity, called "Tulip Gardens: Plants and the Seasons" (http://www.learner.org/jnorth/tm/tulips/AboutFall.html or follow the links from the home page), students are involved in planting tulip bulbs in a garden at their school. Each garden is planted according to a specific set of criteria. Gardens are planted all around the United States and in many areas around the world.

The real, physical activity of planting and measuring the progress of tulips totally engages the minds and emotions of the students. Since each pair of students in my classroom is given their own tulip bulb to observe, measure and plant, he or she takes ownership of what happens to that bulb.

Engagement over time

Once the student takes an interest in his or her tulip bulb, a meaningful connection is made. My students say things like: "My bulb is the biggest, so it will come up first." "This is where I planted my bulb. Look, it's emerging!" "My tulip is the tallest." Because of this vested interest in what happens to their own tulip, students develop a true curiosity about tulip gardens in other locations. This oddly shaped, smelly, sticky, onion-like bulb is the "hook" that catches and keeps their interest for the duration of the investigation. This activity of planting in October, hypothesizing and experimenting through the winter, and reporting the first emer-

Measuring and documenting tulip growth

gence in the spring, is the longest running activity I have successfully accomplished.

As tulips emerge in the spring, the date of each garden's emergence is reported to Journey North and the data is disseminated to all the participants. These gardens are then plotted on a large map of the United States in the classroom. I use different-colored pushpins to represent a two week span of dates. For example, red would mark those places where tulips emerged from the first date given through the date two weeks afterwards. For the following two weeks, yellow would mark the gardens emerging.

Seasonal change

After several gardens are plotted, students begin to see a pattern of seasonal change. Although this part of the activity covers only those gardens planted in the United States, several gardens planted in schools around the world and reported on the Journey North site can be included. By comparing the emergence dates of these world-wide gardens to gardens planted at the same latitude, or near the same geological features as gardens in the U.S., students observe similarities and differences in climates.

An additional connection to global climate is Journey North's, "Global Garden Partners" (http://www.learner.org/jnorth/tm/tulips/GlobalComparisons.html). In this activity, students, classrooms, or schools can partner with a school in the United States or in another country and compare weather, climate, geography and other variables. This activity can be simple or expansive, depending on the teacher's comfort zone and course flexibility. I have always been able to try these "connection" activities, offered by Journey North, on a simple scale and let my classes determine the direction it will take.

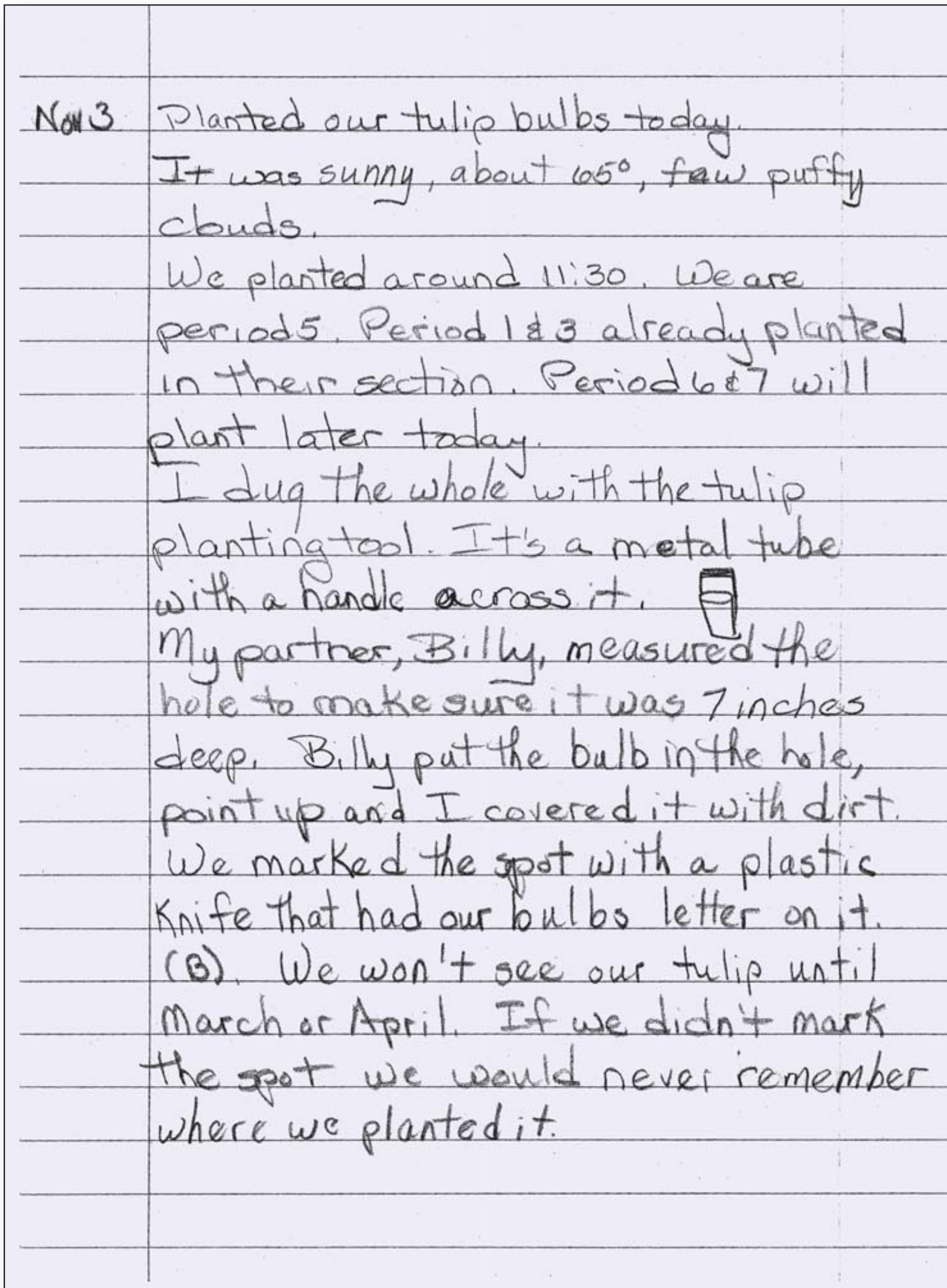
What if…?

An activity that started out as simple and grew in complexity as I repeated it each year is the "What if…?" experiment. The first couple of years of participating in the Tulip Garden Project, I brainstormed ideas for experimenting with the tulip bulbs with each class and then guided the whole class into choosing one experiment. Of course the favorite every year was planting the bulb upside-down, but my blackboard of students' ideas was always filled.

Even though some ideas here were not feasible, even dangerous, I included any idea on the board. Those unusable experiments were discussed by the class and eliminated from the choices. This is an excellent way to discuss the criteria for designing a good experiment without giving the students "rules."

In later years, I was comfortable giving each pair of students an extra bulb for experimentation. This expanded into planting some outside and creating an indoor area of experiments. Many of the students shared their bulb with other pairs of students in order to have more than one "test" subject for their chosen experiment. These experiments helped the students understand how the tulip bulb truly worked. For example, one group removed several of the bulb's scales (layers) and then wrapped it in several layers of newspaper to determine if the scales were more than just insulation.

The newspaper-wrapped bulb was planted outside, according to the rest of the planting criteria. In the spring, after the "official" tulips had been up for a few



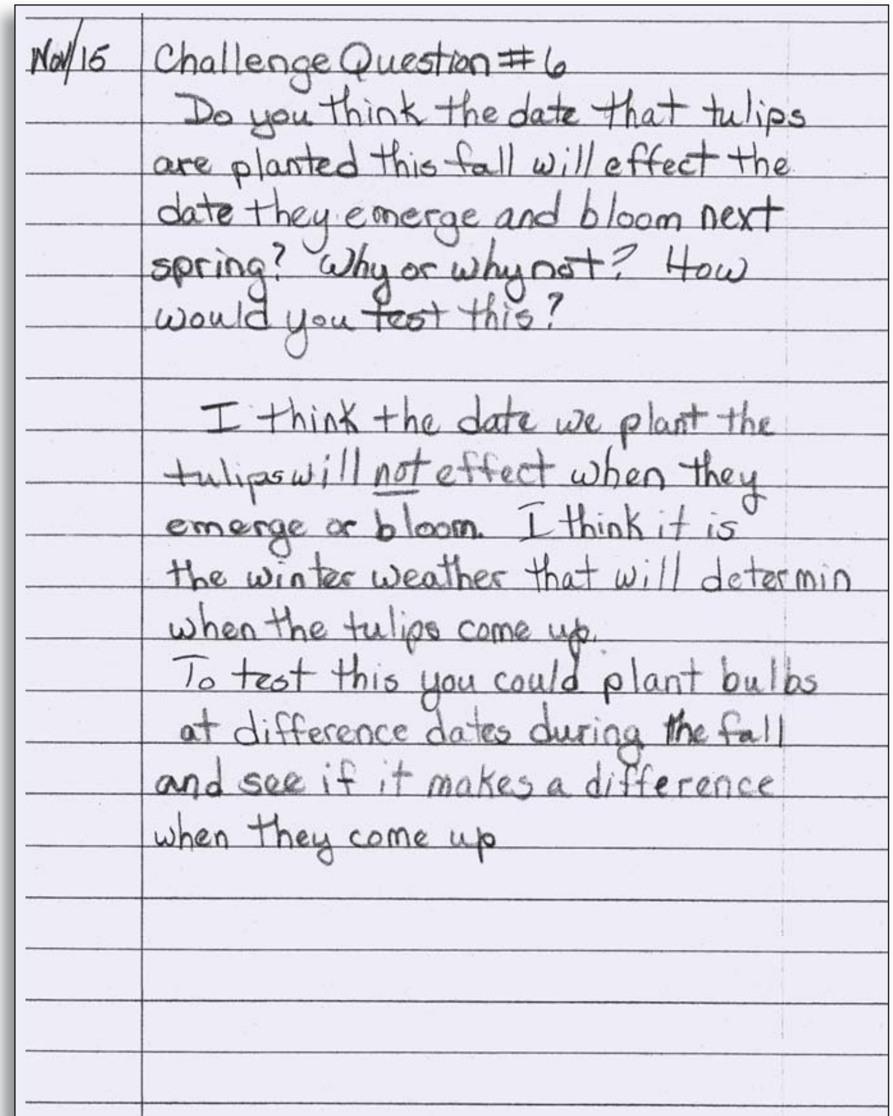
Nov 3 Planted our tulip bulbs today.
It was sunny, about 65°, few puffy clouds.
We planted around 11:30. We are period 5. Period 1 & 3 already planted in their section. Period 6 & 7 will plant later today.
I dug the whole with the tulip planting tool. It's a metal tube with a handle across it.
My partner, Billy, measured the hole to make sure it was 7 inches deep. Billy put the bulb in the hole, point up and I covered it with dirt.
We marked the spot with a plastic Knife that had our bulbs letter on it. (B). We won't see our tulip until March or April. If we didn't mark the spot we would never remember where we planted it.

Each student had their own journal for recording science events throughout the year.

weeks, the students dug up their bulb and discovered that it had begun to grow, but did not break the surface. The discussion of why the tulip stopped growing led them to realize that the layers of the bulb were not just insulation, but a source of nutrition until the sprout can reach the surface and make its own food. Once the students understand more about the way things grow, they have a stronger base for understanding changes in growing activities around the world, increasing their ability to make educated observations of climate changes.

Another component of the Tulip Garden is keeping track of the data from a single garden over a number of years. Having participated in this project since 1996, I have eleven years of data. The planting, emerging, and blooming dates can be compared over several years. This opens a discussion of similarities and differences in weather conditions over time.

There are several schoolyard gardens across the United States and the world that have planted tulip bulbs at the same site, for many years. The data related to any of these gardens is accessible through the



Nov/16 Challenge Question #6
Do you think the date that tulips are planted this fall will effect the date they emerge and bloom next spring? Why or why not? How would you test this?

I think the date we plant the tulips will not effect when they emerge or bloom. I think it is the winter weather that will determin when the tulips come up.
To test this you could plant bulbs at difference dates during the fall and see if it makes a difference when they come up

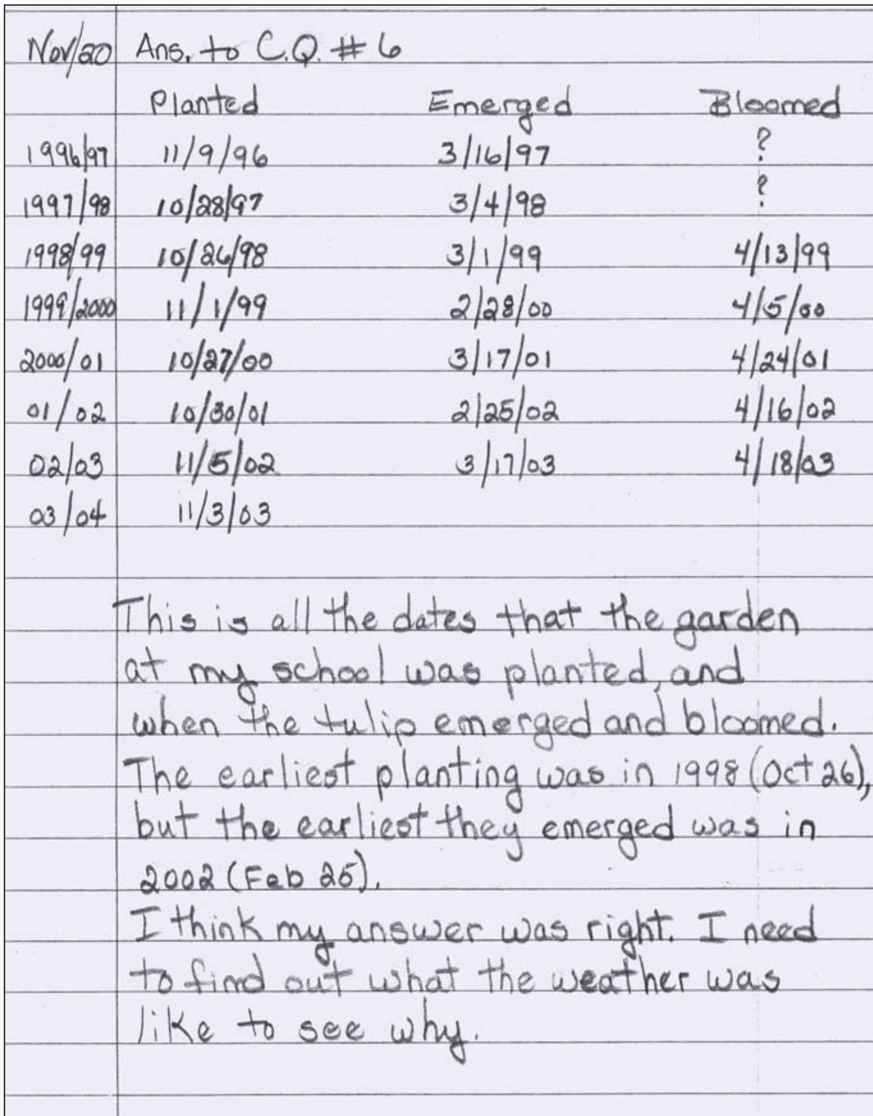
Challenge Questions were the best way to encourage analytical thinking and to assess student progress in self evaluation.

Journey North Web site. Analyzing the data over several years leads to a discussion of the kind of observable facts that will show what is happening to climates around the world.

Recording and reflecting

All data gathered through these activities was recorded in student journals. Each student had their own journal for recording science events throughout the year. What I found worked best was to see that all students had the same kind of notebook and to keep these in the classroom. The inexpensive, composition-type notebook was the right size and fit into the type of box in which each class had its own cubbyhole. The journals were assessed, once per term, for content, organization, and creative thinking. I used a point value for each area assessed, since my grades were based on percentage of points earned compared to total point value of work done. The exact number of points can be determined by how much value is placed on the journal compared to other assessments.

Another great aspect of the student journal was the "Challenge Questions" provided through each Journey North activity. One or more challenge questions were posed in each weekly update. I would choose some of these for my students to answer in their journals. The update, following publication of the questions, would contain either the answer to the question or an expert's opinion on the answer. My students were then required to assess their own answers, not as right or



Nov/20 Ans. to C.Q. #6

	Planted	Emerged	Bloomed
1996/97	11/9/96	3/16/97	?
1997/98	10/28/97	3/4/98	?
1998/99	10/26/98	3/1/99	4/13/99
1999/2000	11/1/99	2/28/00	4/5/00
2000/01	10/27/00	3/17/01	4/24/01
01/02	10/30/01	2/25/02	4/16/02
02/03	11/5/02	3/17/03	4/18/03
03/04	11/3/03		

This is all the dates that the garden at my school was planted, and when the tulip emerged and bloomed. The earliest planting was in 1998 (Oct 26), but the earliest they emerged was in 2002 (Feb 25).
I think my answer was right. I need to find out what the weather was like to see why.

Students assess their own answers, not as right or wrong, but how their thinking compares to the answer given.

wrong, but how their thinking compares to the answer given. I found that most students could not resist first saying whether their answer was right or wrong, before they evaluated how they arrived at that answer.

One challenge question in particular helped to make the leap to global climate comparison. The students were given the longitude and latitude of Haines High School in Haines, Alaska and Mikela School in Espoo, Finland, and then instructed to find them on a world map. After comparing physical and geographical features of both, the students were asked, “Which school will see tulips first? When do you predict the schools in Haines and Espoo will see their tulips emerge? Give reasons for your predictions.” challenge questions were the best way to encourage analytical thinking and to assess student progress in self evaluation.

The Journey North programs are the perfect tool for getting started on global climate observation, not only through tulip gardens, but through the migration of several animal species. Each of these studies provides global data, challenge questions, and firsthand participation in the study of seasonal changes. The educator, whether in public, private, or home schools, can use these tools to enhance student involvement in true scientific inquiry.

Holly Cerullo is a retired seventh-grade science teacher. Her school garden was one of the 13 original Journey North Tulip Gardens and she continues to plant an official tulip garden each fall. She also keeps up with Journey North Monarch and Robin Migrations and occasionally provides a challenge question for students.

Finding Global Solutions for a Global Problem

by Julie Casper

When I first began teaching sixth- to eighth-grade students about the realities of climate change, I was surprised at their perceptions of what the term actually meant. I generally received two answers: (1) the temperature will just get a few degrees warmer and (2) it has something to do with a hole in the ozone layer. Wow! Warmer temperature is part of it and a hole in the ozone layer is a completely different issue.

There is now overwhelming evidence that human activities are changing the world's climate, and it's more than just a warming trend. Increasing temperatures will lead to changes in many aspects of weather, such as wind patterns, the amount and type of precipitation, and the types and frequency of severe weather events. These changes could have unpredictable environmental, social, and economic consequences.

Due to the explosion of information technology today through media such as the Internet, Global Positioning Systems (GPS), Geographic Information Systems (GIS), and remote sensing (satellite image technology), scientists are able to map, collect, and study data over all parts of the Earth. Information acquisition has become global. This creates a perfect opportunity to study climate change in the right perspective—*globally.*

Relationships: how systems are connected

Climate change is a global phenomenon. There are cause-and-effect relationships on many different scales; everything is related in some way. Although each place may have unique characteristics, it has something to offer to the big picture. This concept is important to understand because harmful actions (such as polluting the atmosphere) can impact large areas, just as efforts to reduce pollutants can have far-reaching effects. The entire planet is affected because we all share the same atmosphere. An example of this is when a major volcanic eruption occurs, the ash can travel extensive distances around the world. Another way to illustrate this is to look at a food chain that represents the wildlife in your area. If a key species within the food chain is removed, it will affect the balance—and perhaps survival—of the entire ecosystem.

Global scale: looking beyond your own environment

Because functioning systems are connected, the spatial component is important. Complex phenomena can be better understood spatially through mapping. For example, using resource maps, climate maps, wildlife habitat maps, or vegetation distribution maps enables students to visually conceptualize geographic occurrences. As climates change, they affect the *distribution, extent,* and *abundance* of resources. Illustrating these changes and distributions on maps gives students a visual perspective.

Introducing maps when discussing global phenomena also gives us an opportunity to discuss the practical issues concerning data quality, standards, acquisition, data sharing, and data types, for example:

Who collected the data?
How was it collected?
How was it measured?
What type of equipment was used?
What is the accuracy?
Was it collected in metric units?

This is a good time to discuss why data needs to be collected carefully, accurately, consistently, and needs to be well documented—a term called *data integrity.* It also brings up issues such as the size of the geographic area to which you can apply the data, as well as how far back in time you can infer conditions.

At this point, I have my students begin thinking outside of their own environments.

We do this in a brainstorming session in the classroom. First, I introduce some global concepts of climate change. Then, students apply this knowledge to practical management, modeling, and planning, as if they were the ones making the critical decisions about these very issues in the near future (which some of them no doubt will be). Examples of broad topics we discuss may include:

Natural resource issues: Today, one-third of the world's population (about 2 billion people) already suffer from a shortage of water, and this number is expected to increase dramatically as the global population increases. Climate change could add to the stress on fresh water supplies. Drought-prone areas could receive even less precipitation; glaciers and mountain snowcaps that feed rivers and streams in many parts of the world are already retreating. In Africa, for example, more than 80% of the ice field that existed on Mount Kilimanjaro has melted since 1912.

Economic and security issues: In regions where growing food is already difficult, reduced water resources could make it even harder to feed people. This could lead to the migration of millions of "climate-change refugees" to other countries.

Economic and ecosystem issues: Sea levels will begin rising and flooding all the coastal areas. Adapting would cost millions of dollars to modify coastal structures and millions of people and wildlife species would be impacted.

Health issues: Scientists project heat waves will kill thousands of people. Tropical insects that spread diseases such as malaria and dengue fever could expand their habitat range as it becomes warmer. Increased air pollution may lead to more deaths. Changes in wind and weather patterns will change the amount of plant pollen and mold spores, negatively impacting people with allergies.

Ecosystem issues: As sea levels rise, increased erosion and flooding will occur, as well as heavy destruction from storm surges.

Safety issues: Climate change may increase the severity of weather events, such as hurricanes, tornadoes, thunderstorms, ice storms, floods, and droughts. They may occur more often and be more intense. As areas become drier, there will also be more wildfires threatening the landscape and homes.

With that to think about, and looking beyond their own environment, I pose questions for students to consider, such as:

How will a drought in California citrus groves affect consumers in New York? *(availability and price of fruit)*

How will a hurricane in Texas affect people in Montana? *(gasoline supply and price)*

How would Utah's tourist economy be affected by a mild winter? *(Skiers would choose to go elsewhere on winter vacations)*

When the students start brainstorming these cause-and-effect scenarios, they begin to see how systems are interrelated and why the "whole picture" approach works better for a topic like climate change. I had one student say that if southern California's climate changed and they had too much rainfall and flooding, it would ruin going to the beach and Disneyland, which is something her family did each year. The class agreed that excess rainfall and flooding would hurt southern California's tourist industry. This concept then links to the real world and how management issues are decided.

Students…see how systems are interrelated and why the "whole picture" approach works better for a topic like climate change.

Management issues

There are many management issues involved with climate change, depending on the nature of the situation and what needs to be managed. In natural regions, places often fall into specific physiographic categories that require management plans, tailored to their individual needs.

Because there are several distinct physiographic regions in the United States, I've

Figure 1

found that one of the best ways to convey the multiple aspects of climate change is to first introduce the students to the type of region they live in, then examine other regions in the country. This way, students get a good feel for the similarities and differences between areas and what that means in terms of responding and adapting to future change. An excellent Internet resource for this is: http://yosemite.epa.gov/oar/globalwarming.nsf/content/natural.html (Figure 1).

By clicking on a region, you can bring up specific climate change information relevant to that geographic area.

Abstract and application thinking skills

Modeling, predicting, and planning are critical concepts that students acquire. To gain these, they must understand and use abstract and application thinking skills. Because my students were in the Intermountain West (Utah), we focused on the Mountain Region portion of the natural regions. I asked students to focus on two important aspects within the region: water resources and wildlife habitat. We developed the following table in regard to some of the significant issues related to water resources:

Modeling *(What is the situation?)*	Predicting *(What is its effect?)*	Planning *(What action is needed?)*
Less water available	Lower river runoff; Lake levels drop; Less drinking water available; Impact to cities, recreation, farming, and ranching.	Control water allocation; Sell water rights; Ration water; Use conservation methods for farming and ranching; Control, reduce recreation.
Flooding	Land erosion; Residential damage; Drinking water pollution.	Control landslides and mudslides; Build retaining walls; Plant vegetation to stabilize ground; Build control structures and diversions.
Vegetation stress	Lower productivity on farms; Yards and landscape ruined; Golf courses and parks impacted; Loss of ecosystems.	Farming conservation practices; Use xeriscaping (low water demand landscaping); Allocate/ration the water; Monitor fire hazards for wildfire.

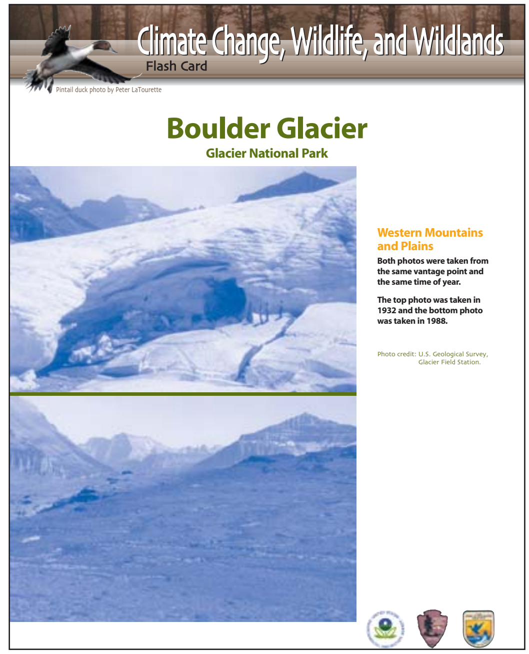


Figure 2

When putting this table together, the students looked at basic situations as well as the associated consequences and areas where planning would need to be involved to cope with the impact. They created the beginnings of a basic working plan you'd find in a real management endeavor.

Utah is home to quite a few national parks, state parks, national forests, wilderness areas, and wild and scenic rivers. Because of this, it provides habitat to a wide variety of wildlife. Currently, the state and federal governments protect much of this habitat. As the climate changes, however, scientists tell us that ecosystems will shift both northward and higher in elevation. Unfortunately, as this happens, the areas that offer protection today may not offer protection in the future. When looking at this issue in terms of application-related objectives, the students were able to come up with strategies such as:

Begin acquiring new areas where migration may occur;

Setting up buffer zones of "migration corridors" to accommodate existing wildlife.

Interactive and relational thinking skills

Finally, to put it all together, I asked the students to make some proposals based on

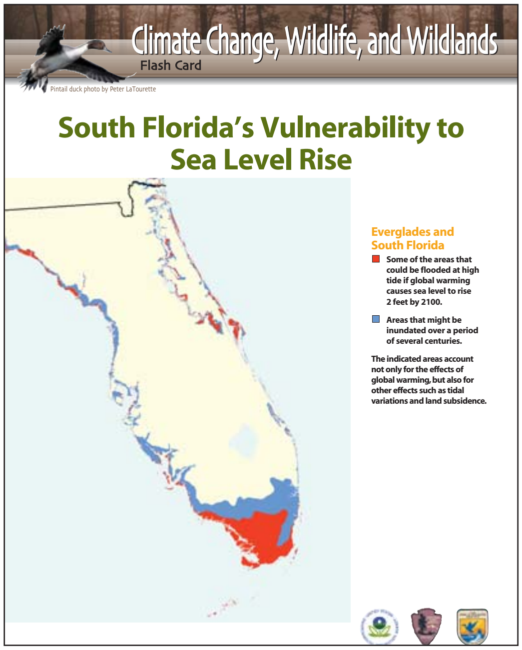


Figure 3

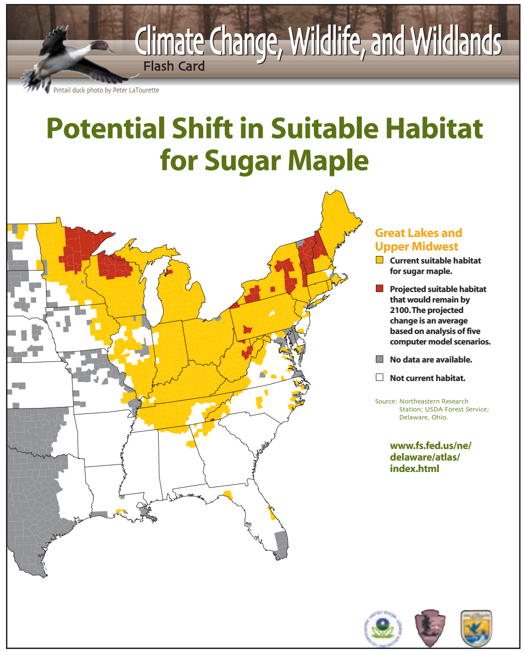


Figure 4

what they'd learned about the practical consequences of climate change and key decisions they would make if they were the managers. After a brainstorming session this is what they came up with. They would:

Make laws enforcing more efficient use of water;
Educate people on how much climate change will affect everyone's lives worldwide;
Have educational programs in high schools and colleges;
Create positions in the government that deal specifically with climate change and stopping it;
Have the government give tax credits to those that take action to do their part (such as participate in the ENERGY STAR® program).

Next, I showed my students three images and asked them now how these would affect them, even though they related to other areas of the country (Figures 2, 3, 4). It was rewarding for me to observe the interactive dialogue that students started over melting glaciers, rising sea levels, and shifts in vegetation. One of my students had visited Glacier National Park in Montana the previous summer and reported to the class that she'd learned from the Park Interpreter that all the glaciers there were disappearing and would be melted in just a few decades if the climate kept warming. Her question was, what would the Park Service do with a Glacier Park that had no glaciers in it anymore? Another student asked to see a current map of Florida so he could compare the sea level rise map to it. We compared the maps so the class could get an idea of which towns and cities would disappear if the water level rose, and that put it in a more realistic perspective for them to see that we were actually talking about real places with real people, not just a place on a map.

At that point we discussed action plans that individuals, families, communities, states, countries, and even the world, could do to slow global warming and climate change—further proof that we are all connected. ✎

Web sites

http://yosemite.epa.gov/oar/globalwarming.nsf/content/natural.html. The Web site with the "natural region" information also has selectable information on a statewide basis highlighting each individual state's aspect of climate change, solutions, action plans, legislative initiatives, and state greenhouse gas inventories.
http://epa.gov/climatechange/wycd/school.html.
http://epa.gov/climatechange/wycd/ORWKit.html.

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Climate Change Meets Ecophobia

by David Sobel

Ever since Al Gore's *An Inconvenient Truth* brought global climate change firmly into the public consciousness and public schools, the cards, letters and e-mails keep on coming. "Is it really appropriate for third graders to watch this movie?" worried parents and teachers ask me. Their deep concern: Is it useful, or counterproductively upsetting, for children to be educated about the world going to hell in a handbasket?

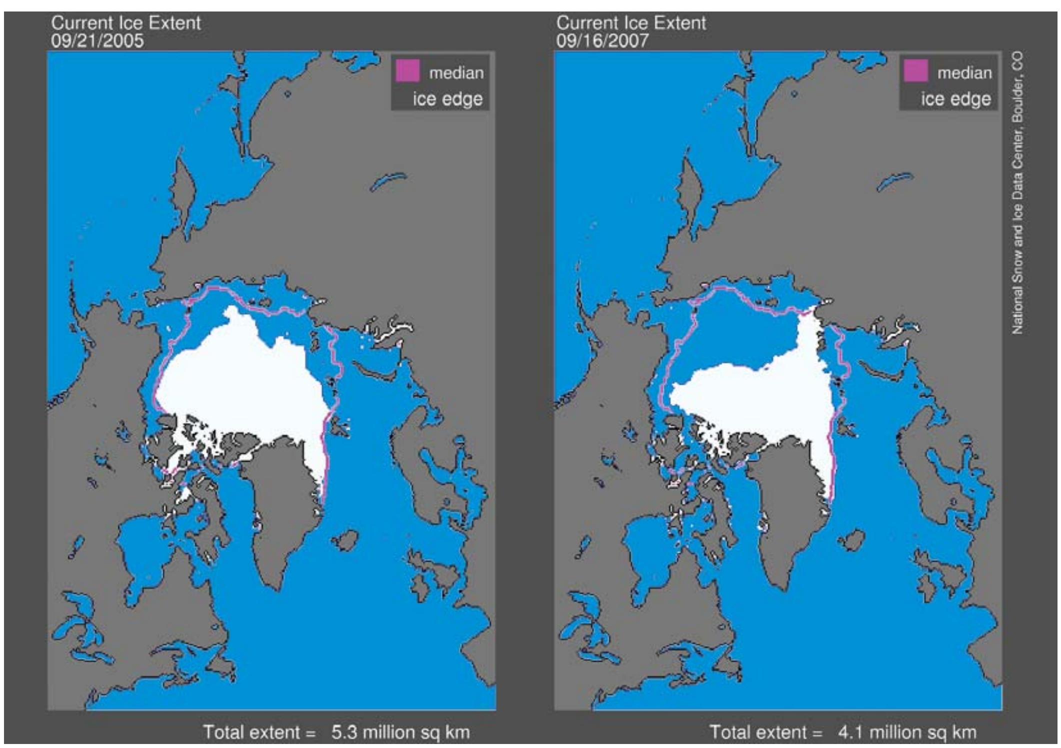
People ask me because about ten years ago I wrote a little book called, *Beyond Ecophobia,* advocating for honoring developmental appropriateness in environmental education. At that point, I railed against premature rainforest education for young children. I was concerned about the curriculum message that *the rainforest is being destroyed and it's your responsibility, first graders, to save it!* This would have been like asking us children growing up in the early 1950's to find a cure for polio.

In a "My Turn" essay of an August, 2004 *Newsweek*, Brookfield (Illinois) Zoo educator and parent Katie Johnson Slivovsky framed the dilemma well in pointing out the problem with some eco-ardent children's literature—in this case a book about extinct animals for pre-schoolers. Here's her portrait of reading this book as a bedtime story.

> *"'L' is for Las Vegas Frog…People built the city of Las Vegas and paved over all the freshwater springs where this frog used to live. Sadly, we say good-bye to the Las Vegas frog."* The very last sentence of the book is, *"Let's hope humans never become extinct."*
>
> "Night-night, Jimmy."

Hurricanes, oceans, and icecaps, oh my!

The same thing is happening right now with global warming education. The ice caps are melting, mosquito populations are expanding and spreading serious diseases, hurricanes are getting windier, and we need children to



This image from the National Snow and Ice Data Center shows a dramatic decrease in the arctic sea ice extent between September of 2005 and September, 2007. For more information: http://www.nsidc.org.

understand that it's their responsibility to fix these problems. But no pressure!

Numerous media projects are in the works to address the current problem of global climate change and the solution, education for sustainability. There's a puppet-based television show aimed at four- to six-year-olds, another PBS animated program aimed at eight- to ten-year-olds, and child-sensitive versions of *An Inconvenient Truth*. I've recently been asked to be on three different advisory boards and to write the foreword for a new book on the science of global warming by noted children's book author and illustrator, Lynne Cherry. Yikes! What do I say?

On the one hand I believe that global climate change is caused by human behavior and we've got to do something about it fast. On the other hand, I'm concerned that prematurely recruiting children to solve this overwhelming problem will just make them feel helpless and hopeless, instead of motivating them to walk to school instead of riding in their parents' cars.

I'm reminded of the Godzilla meets Rodan movies of my childhood. Godzilla is Global Climate Change and Rodan is Developmentally Sensitive Environmental Education. They're battling in the Tokyo of my mind and my convictions are getting trampled. So here's my attempt to conduct a bit of conflict resolution between the two.

The horns of the dilemma

Parents and educators are of two very different minds when faced with this dilemma. After being trained as a global climate change educator by Al Gore and National Wildlife Federation educators, Lisa Shimizu, a programmer at the Seattle rock station KEXP, decided to create a child-friendly version of the slide show, *An Inconvenient Truth*. She simplified the content, mollified some of the tragedy, kept a reasonable amount of graphs and charts and targeted it for use with eight- to ten-year-olds. After showing it to a large family audience with lots of elementary-aged children, an interesting Web dialogue ensued that framed the divergent points of view on the issue.

One parent, reflecting some of my concerns, said:

> One concern to at least be aware of is that if we hit kids (before 6th grade) too hard with environmental problems, they learn the facts, understand the issues are important, but don't become more environmentally active. Instead they may be overwhelmed. Younger kids may best be served by following the lead of Rachel Carson, and building a sense of wonder and love for the earth.

Responding to the above comment, another parent scoffed:

> My son attended this show. He loved it and got a lot out of it. To those of you who worry about age-appropriateness, and unintended consequences, I say, "Oh come ON!" Obviously the critics haven't seen the show.... In America we've grounded out kids with materialism, egoism, violence, killing, convenience at any cost...and you're worried about Ecophobia?
>
> Never mind that we are past the point of pussyfooting around. Our generation hasn't shown itself to have the gumption to fix our mess, so it falls upon our kids to actually do something. If we don't send children the message now while they're young, they'll grow up to be the greedy, consuming jerks we are.

It's easy to see the virtue in both of these perspectives. Clearly both parents are after the same thing: figuring out the right way to educate children who will rise to the challenge of living ecologically responsible lives. Assuming that many of us agree on this point, let's look at what we know about creating learning settings that effectively cultivate ecological behavior.

Knowledge, attitudes, and behavior

Ten years ago I met with a prominent environmental funder in Boston to advocate for environmental and place-based education and how they help increase students' academic achievement. Impatiently, he responded,

The ice caps are melting, mosquito populations are expanding and spreading serious diseases, hurricanes are getting windier, and we need children to understand that it's their responsibility to fix these problems. But no pressure!

"Well, test scores are all fine and good," he acknowledged, " but what I really want to know is if these programs help kids become better stewards of the land and water. Does place-based education actually change their environmental behavior?"

Good question. And the answer to that has been changing over the past couple of decades. The conventional assumption in environmental education starting in the 1960's and 70's was that knowledge led to attitudes which led to behavior. In academic terms, Hungerford and Volk summarize, "If we make human beings more knowledgeable, they will, in turn, become more aware of the environment and its problems and, thus, be more motivated to act toward the environment in more responsible ways."

We've been spending way too much time focusing on conveying environmental knowledge and way too little time on developing environmental behaviors.

Let's look at how this might work. We teach kids that burning gasoline in cars produces carbon dioxide and that carbon dioxide causes global warming. As a result, they develop the attitude that limiting one's consumption of fossil fuels is a good and virtuous thing to do. Then, when it's time for them to buy a car (here's the behavior), they'll opt for the Prius over the similarly-priced, flashier, but fuel-guzzling, Firebird.

Sounds good, but as Hungerford and Volk indicate, "Research into environmental behavior, unfortunately, does not bear out the validity of these linear models for changing behavior." Or more simply, it ain't necessarily so. Just because children know that burning fuel creates carbon dioxide and that this is bad for the planet, they don't necessarily develop ecologically responsible buying patterns as adults. Increased knowledge and change in attitudes doesn't necessarily translate into different behavoir.

We can help children to understand their actions make a difference. Turning off the lights when we leave a room saves money.

One of the problems with this model is its assumption that knowledge precedes behavior. Schools have construed this to mean that it's the school's responsibility to provide the knowledge and maybe the attitudes now—the behavior will take care of itself in the future. So we assume that all this good learning will lead to good behavior later. This, in turn, means we are less likely to use schools to practice, in little ways, the behaviors we want children to develop in bigger ways later on.

It also turns out that the pathway to responsible environmental behavior is a bit more complicated than: knowledge leads to attitudes leads to behavior. It's more like: a sense of agency and control leads to the knowledge of issues and action strategies, which lead to an intention to act, which under the right precipitating conditions, leads to environmental behavior.

One of the first things you help children to learn is that their behavior makes a difference. Your feeding the kitty keeps the kitty healthy. Turning off the lights when you leave the room saves us money. This sense of personal responsibility leads to wanting to understand why turning off the lights saves money and why turning off the lights reduces carbon dioxide production. The sense of agency leads to a desire for knowledge and a desire to know other skills for reducing carbon dioxide production. This leads to the intention to make other changes, if and when the choices present themselves, which leads to responsible environmental behavior.

At the risk of gross over-simplification, what this suggests is that small behaviors lead to knowledge and attitudes, which lead to medium-sized behaviors, which lead eventually to bigger behaviors. But keep in mind that behaviors are only possible when choices present themselves. If the nearest Prius dealer is 100 miles away, you're probably going to buy the Firebird. If you really believe in recycling, but there's no convenient paper recycling system in your classroom, you're probably going to throw the paper away.

This is all a long-winded way of saying that we've been spending way too much time focusing on conveying environmental knowledge and way too little time on developing environmental behaviors. In addition, in most schools, we've got a situation of, "Do as we say, not as we do." We disseminate knowledge about how environmental systems work but we don't design schools to be models of sustainable systems and, as we know, actions speak louder than words.

Catastrophe and ecophobia

Then there's also the issue of ecophobia—my contention that the overwhelmingness of environmental problems can breed a sense of ennui and helplessness. A fascinating study by the Swiss National Science Foundation (Finger, 1993) looked at the relationship between different kinds of environmental knowledge and environmental behavior in Swiss adults. The study compared adults whose knowledge about the environment was based mostly on media presentations of ecological catastrophes vs. adults whose knowledge about the environment came from extensive nature experiences and activism, mostly at the local level.

Finger found that, "Environmental behavior is less the result of learning and knowledge and more the result of particular environmental experiences," and that, "…some environmental learning does not necessarily translate into more responsible behavior towards the environment and can even be counterproductive."

In other words, too much knowledge about environmental tragedies actually discourages environmental behavior. Knowledge decreases behavior! If global warming is a done deal, why should I bother to do anything about it? If this is true for adults, who have well-developed capacities to shield themselves from information overload, think how this must be affecting children.

The author concludes his study with recommendations for environmental education programs:

First, "Nature experiences seem to be a necessary condition for any type of environmentally responsible behavior.…In particular, nature experiences should be provided for the youngest generation."

Second, "Experiences of environmental activism emerge as another crucial condition for any environmental behavior.… It is necessary that social and collective action be an integral part of any continuing education activity."

Third, "Fear and anxiety of environmental problems has the potential to turn environmental education into a counterproductive activity." Therefore, education about the problems should be substantially counterbalanced by opportunities to address the problem constructively.

Fourth, "When low fear is involved, environmental knowledge and information do make a difference in terms of environmental behavior."

Resonating with Finger's first suggestion above is a 2005 Cornell study by Wells and Leckies that looked at the relationship between childhood experience and adult environmental behavior. They found that, "Childhood participa-

Without that deep abiding sense of comfort in and love for the natural world, no amount of chastising about turning off the lights or biking to school is going to make a bit of difference.

Research suggests a strong link behind childhood nature experience and adult environmental behavior.

tion in "wild" nature, such as hiking or playing in the woods, camping, and hunting or fishing, is positively associated with environmental behaviors in adulthood." Rather than taking eight-year-olds to the Global Warming slide show, it might be more useful, in the long run, to take them fishing or blueberry picking.

What does this all mean for what we do on Monday regarding global climate change education with children? Let's bring together these guidelines with the previous discussion about the relationship between knowledge, a sense of agency, and environmental behavior.

In order to cultivate long-term environmental behavior, it's important to provide ongoing training in environmental activism.

Schools for climate protection

In light of the rapidly accelerating evidence of climate change, and the small window of opportunity in the next thirty years during which we might stabilize climate, the temptation is to jump to direct instruction. *Global warming is breathing down our necks so let's educate the kids to do something about it!* This is what motivated Lisa Shimizu to make her modified version of *An Inconvenient Truth*. And while this might be a virtuous endeavor, it's not the big answer. Instead, we have to take a deep breath and start to do the hard work of shaping classroom and school cultures that will grow stewardship behavior during the thirteen or so years of elementary through high school education. To do this we should honor the recommendations of the Swiss National Science Foundation above.

The first thing we need to do is create comprehensive place-based education programs that connect children and curriculum to the nearby natural world. Keep in mind that much of the available research suggests a very strong link behind childhood nature experience and adult environmental behavior. Without that deep abiding sense of comfort in and love for the natural world, no amount of chastising about turning off the lights or biking to school is going to make a bit of difference.

Next, we have to design schools as communities of care. Schools are used to this mindset in regard to caring for people. The good work of the Northeast Foundation for Children, which trains teachers in the Responsive Classroom, is one example of shaping a positive classroom culture. The change here is that the ethic of care has to be extended to caring for the natural environment and eventually the global ecosystem. Just as teachers develop a set of classroom jobs where all children participate in the daily jobs that keep the classroom functioning, I recommend that schools develop incremental, progressive responsibilities for children at each grade level. These responsibilities would involve every teacher, student, and staff member in shaping a school environment that models environmental sustainability.

For example, some city and education leaders in Keene, New Hampshire have started to explore the idea of "greening" the local school district. Cities for Climate Protection is a nationwide initiative, in line with the international Kyoto Protocols, to reduce greenhouse gas emissions. Over the past five years, Keene has emerged as an acknowledged leader among small New England cities. The conversion of much of the city's fleet to bio-diesel, excellent recycling programs, the use of recaptured methane to generate power for the solid waste facility, and a willingness to redesign some of the road infrastructure to facilitate the reduction of car emissions—are all illustrative of conscious local attempts to green the city.

The idea is to extend Keene's Cities for Climate Protection initiative with a parallel Schools for Climate Protection initiative. The goal would be to evolve the curriculum, staff development, and facilities management aspects of the schools so as to cultivate an ethic of stewardship in Keene students, reduce the greenhouse gas emissions of school operations, and provide models of low impact lifestyles to the broader Keene community.

The Ladder of Responsibility

One core precept of this approach would be to create a developmentally appropriate, school-wide model, a Ladder of Environmental Responsibility, which honors the learning dispositions and capabilities of students and teachers at the elementary, middle and high school levels.

This Ladder would provide a set of incrementally more challenging tasks for children throughout their school career. In traditional agrarian cultures, this Ladder of Responsibility is often seen in children's progressive responsibility for chickens in early childhood, goats in middle childhood, and a horse or cow in early adolescence. The knowledge required, the care-taking skills and the size of the animal increase with the competence of the child.

Similarly, one small independent school in St. Louis has a continuum of outdoor education challenges. In first grade, children do a simple overnight on the schoolyard; in fifth grade they relive Tom and Becky's night in a Missouri cave; by eighth grade they do a weeklong urban service week in a southern city. What we're looking for is a set of stewardship responsibilities for each grade level in the school.

How would this work in a K–6 public school? The teachers and staff would divide the environmental care of the school into seven increasingly sophisticated rungs of environmental responsibility. Each grade level would be assigned to one of the rungs of the ladder. The tasks would involve some kind of daily or weekly attention. The Ladder would be devised in conjunction with the state-mandated curriculum.

Certainly, the science curriculum is one consideration, but all aspects of the language arts, math, and social studies curricula would be considered as well. For instance, garden maintenance responsibilities would be allocated to the grade level in which the Growing Plants science unit is taught. The sixth-grade language arts curriculum focus on persuasive letter writing would be connected to the letters

home to parents about not idling their cars when parked in front of the school. A sample Ladder appears on page 20.

Going back to that Swiss National Science Foundation study, the second recommendation was that, "Experiences of environmental activism emerge as another crucial condition for any environmental behavior. It is necessary that social and collective action be an integral part of any continuing education activity." My translation of this recommendation is that, in order to cultivate long-term environmental behavior, it's important to provide ongoing training in environmental activism. The best way to do that is by embedding children in a culture that gradually ups the ante of responsibility as children mature.

Children are expected to identify problems, devise solutions, advocate for change, meet barriers, accept defeat, celebrate successes, keep trying. By working on small, manageable, cognitively accessible environmental problems at the micro level, we'd be developing the sense of agency, the locus of control that Hungerford and Volk identify as one of the crux elements in shaping persistent stewardship behavior. It's this kind of cultural modeling that will provide the durable commitment to dealing with the more expansive, heavy problems of global warming at the community, regional and national levels as children become adolescents and adults.

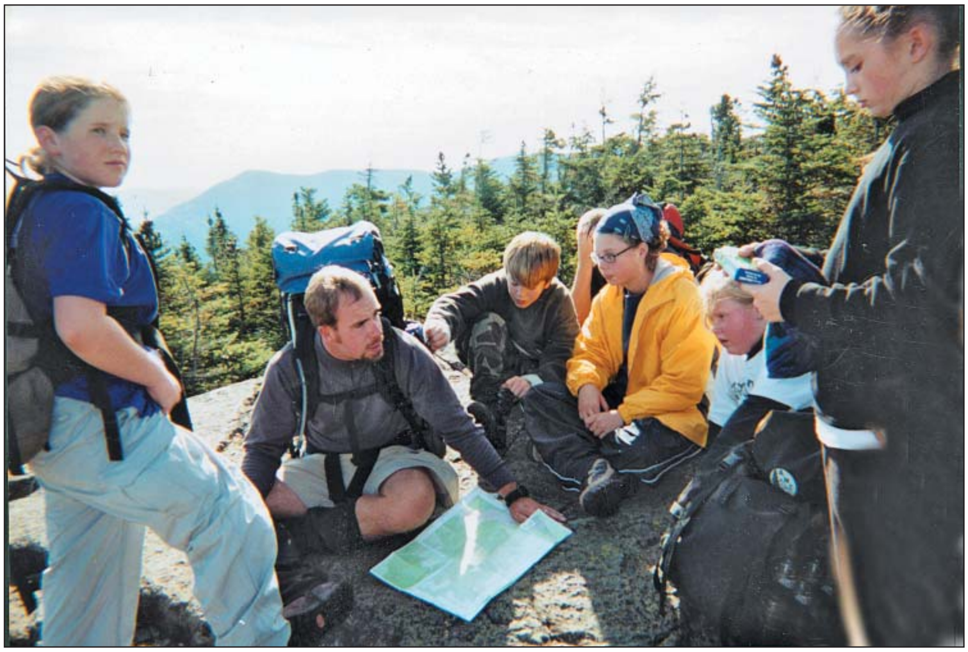
Just a pipe dream? I don't think so. Pieces of this kind of approach have taken root in schools across the country. Schools are rethinking school lunch, creating

The best way is by embedding children in a culture that gradually ups the ante of responsibility as children mature.

LADDER OF ENVIRONMENTAL RESPONSIBILITY

A Model for Elementary Schools

K:	**Seasonal School Beautification:** Teachers and students responsible for weekly displays of flowers, rock gardens, winter twigs, and the natural displays that fit with seasonal celebrations of the solstices and equinoxes.
1st:	**Flower Garden Maintenance:** Teachers and students weed the gardens, put them to bed for the winter, start seedlings in the late winter, run the plant sale in early spring, bring the garden to life, install new plantings.
2nd:	**Schoolyard Vegetable Gardens:** Teachers and students install raised beds, test and amend the soil, harvest vegetables, arrange for the harvest festival, put the garden to bed, put up the pickles, order the seeds in the spring, plant the garden, organize the volunteers for summer maintenance.
3rd:	**Maintaining the Schoolyard:** Teachers and students keep the nature area or schoolyard clean, devise graffiti and vandalism prevention programs, help to teach schoolyard games, work with school maintenance staff, create homes for wildlife, keep the bird feeders full, keep the running record of birds that visit the feeders.
4th:	**Running the Recycling Program:** Teachers and students design and run the paper-recycling program. They collect the paper and bring it to the collection site, and they monitor classroom and school use in hopes of decreasing paper usage. Systems for other materials such as glass, aluminum cans, and inkjet printer cartridges are developed as the system matures.
5th:	**Tending the Composting Program:** Teachers and students work with school lunch staff to first design a pre-consumer composting program and eventually a post-consumer program. Fifth graders educate new students about what's compostable and what isn't. They also staff the post-lunch separation process. When the system matures, post-snack systems are developed as well.
6th:	**Climate Change Team:** Teachers and students are responsible for minimizing the carbon dioxide output of the school. They accomplish this with yearly projects to monitor and reduce electricity, heating fuels, and water consumption in the school. Students suggest changes in student/teacher/staff behavior to reduce consumption. Students and teachers work with building maintenance staff to use the healthiest cleaning products with the least emissions.



As students grow older, they take on more complex outdoor challenges.

biodiesel for school vehicles, initiating anti-idling campaigns, creating schoolyard wildlife habitats. The Ladder of Responsibility is an idea just waiting to happen. Be the first school in your community to create one and then let us know how it's working.

David T. Sobel is the Director of Teacher Certification Programs in the Education Department and Director of the Center for Place-based Education at Antioch University New England in Keene, Hew Hampshire. One of the founders of The Harrisville Children's Center, he is a member of the editorial board of the journal, Encounter: Education for Meaning and Social Justice, *and has served as a correspondent for* Orion *magazine. He is author of* Children's Special Places, Beyond Ecophobia: Reclaiming the Heart in Nature Education, Mapmaking with Children: Sense of Place Education for the Elementary Years, *and* Place-based Education: Connecting Classrooms and Communities. *David is currently co-director of Project CO-SEED (Community-based School Environmental Education).*

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Technology for Learning

Understanding Variability and Change

by

BOB COULTER

In my "day job" as director of an ecology center, I often have to wrestle with how to engage students in big issues such as climate change. After much consideration and discussion with colleagues, I remain ambivalent. On the one hand, of course we want students to understand how the Earth works, and how humans have an impact on the environment. On the other hand, an issue such as climate change can leave kids feeling hopeless and disempowered. More pragmatically, the evidence for climate change is likely to be hard to grasp, at least for a pre-teen child. For a student who at best has an unsophisticated understanding of ecosystem dynamics, they are likely to think along the lines of "What difference does a degree or two make? Anyway, what can I do about it?"

Despite these misgivings about teaching climate change to younger students, I do think there is important work teachers can do to lay the foundation for more complex work to be undertaken as students mature. Specifically, helping students as they mature to develop a more sophisticated and nuanced understanding of variability and change can equip them to better interpret the evidence supporting global warming claims. Since this same understanding of variability and change is very age-appropriate and useful for younger students, it has benefits both now and in the future. In essence, what I'm proposing here is a dual-use pedagogy: useful for students now and for building future capacity.

As a starting point, we need to help students to understand what's typical in our local area, and use that as a point of comparison. The "normal" average temperature in St. Louis for yesterday's date was 74 degrees.[1] In fact, the average temperature for yesterday was 83 (based on a high of 94 and a low of 72 degrees). Thus, we were 9 degrees above normal. Last year was a degree below normal; the year before that two above normal. Back in 1997, we were 13 degrees below normal.

Given this variation, how can students make sense of it? Organizing data into a table provides a good start. Using any spreadsheet program, you can enter the daily data and the longer-term "normal" data for the date, and then use a third column to calculate the difference. As you can see in the accompanying table, there is no clear pattern in the data showing a trend over time. Note the swing from 1997 being 13 degrees below normal to 1998 being 9 degrees above normal. Overall, the past 16 years of data shows that September 4th in St. Louis has been, on average, 1.125 degrees above normal.[2]

Questions from the data

This of course, raises a new set of questions: Is sampling one date through time enough to draw conclusions? Would the data for September 3 or 5 show different results? Should we look at longer time frames, such as a monthly or annual average? Generally, variation over a longer term isn't as pronounced as the daily variation, since some values will inevitably be higher than normal and others lower than normal. Asking your students to make predictions and justify them will be a great opportunity for you to assess their level of understanding on these topics.

If your students track temperature data for a month, they can see this for themselves. Many local newspapers, as well as a number of Web sites focusing on providing weather data, include the high, low, and normal readings for your local area. Students can record the

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previous day's high and low temperatures and calculate the average temperature for the day. This can be compared with the normal temperatures for the date to generate an interesting data set.

For the month shown in the line graph, you can see that individual dates varied quite a bit from normal, but the month as a whole turned out to be pretty typical with an average temperature that is only 0.03 degrees above normal. In essence, the warm spell in the middle of the month balanced the colder-than-normal couple of days to start the month. Likewise, by looking at the table used to generate their graph your students could find dates in your study that balance each other out. This would give even younger children a very concrete way of thinking about measures of central tendency like mean and median.

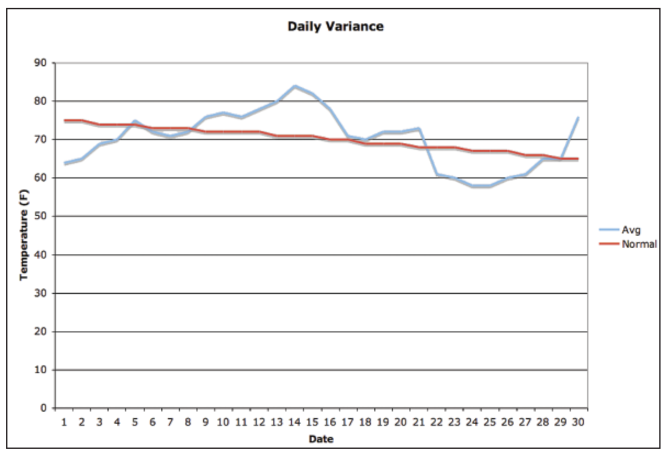
	A	B	C	D
1		Daily Avg	Normal	Difference
2	1992	74	74	0
3	1993	70	74	-4
4	1994	70	74	-4
5	1995	77	74	3
6	1996	76	74	2
7	1997	61	74	-13
8	1998	83	74	9
9	1999	80	74	6
10	2000	74	74	0
11	2001	81	74	7
12	2002	78	74	4
13	2003	68	74	-6
14	2004	78	74	4
15	2005	76	74	2
16	2006	73	74	-1
17	2007	83	74	9
18		Average difference:		1.125

Understanding variations

Throughout this process, your students will develop some essential understandings about data, including the fact that there is inevitably variation within a data set and that this variation can be described and managed. Students can also begin to develop their understanding of how time frames matter: When we look at a single day (or a single instance of anything) we are more likely to see variation than if we look at a longer time period. Turning that concept around, students can begin to develop an understanding that when a change is sustained over a longer period, we can have more confidence that there is something significant going on.

This is the crux of the climate change argument: Over decades or even centuries, there has been a measurable change in the climatic conditions on Earth. When your students are ready to grasp this, they will have a more sophisticated perspective than the many people who write off every warm day as global warming or use a cool day as evidence that there is no such thing.

More immediately, this enhanced understanding of weather and climate data can be useful in a wide range of environmental investigations. When my students saw their Journey North tulip bulbs emerge much earlier one year than they had in the previous year, they were able to attribute that to the unusually warm spring they had documented. Similarly, understanding these trends helps interpret migration timing, trees "leafing out," and a host of other phenomena. Branching out into other disciplines, one possible investigation is to have your students analyze census data to describe their community, and perhaps how it has changed over time.



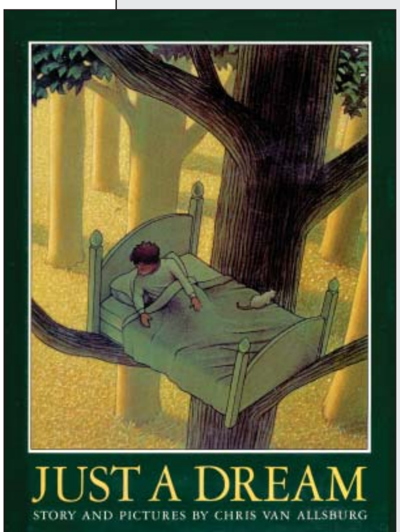
There is great learning potential here, all starting with a better understanding of variability and change.

1. Average temperature is usually defined as the average of the daily high and low—a simple but quirky definition that lends itself to some very interesting mathematical investigations. For example, would you get different results if you took the average of 24 hourly readings instead of just the high and the low?

2. Historical temperature data for your community can be obtained through a "premium" subscription to http://www.accuweather.com. A 30-day free trial is available to see if the data meets your needs.

Literature Links

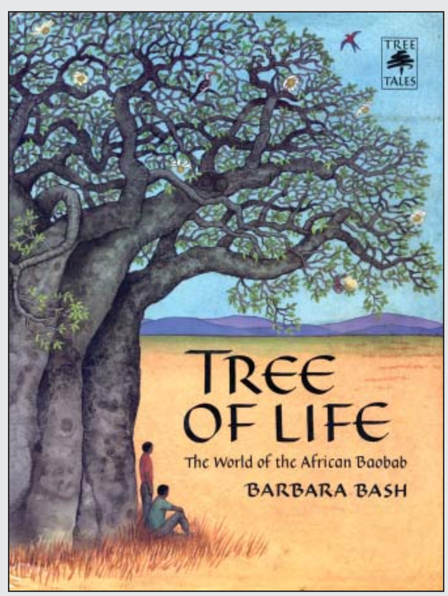
As you look for literature to support your studies of climate, remember that there are also thousands of great titles dealing with organisms or phenomena on their own—such as stories involving migration, noticing changes, indicator species, etc. Don't limit your search to specifically "global climate" titles. Here are a mixture of both kinds of books, including both fiction and non-fiction for children.



Just a Dream, by Chris Van Allsburg (Scholastic, 1990), is now somewhat of a classic in assisting children to imagine their world and see how small, individual actions can lead to change on a greater level. Two very different children are neighbors. Walter can't see the point in taking time to separate trash, or why Rose would choose a tree for her birthday present (instead of a game or high-tech gizmo that he'd like). At night, Walter's bed takes him to the future, where the consequences of his actions are made clear with enormous exaggeration. Mountainous landfills, smog-filled air, and a hotel atop Mt. Everest help him decide to make changes in his own life. A bit heavy on the cautionary side but still very enjoyable for five- to nine-year olds. This is a great book to use to initiate a discussion about our own habits of living.

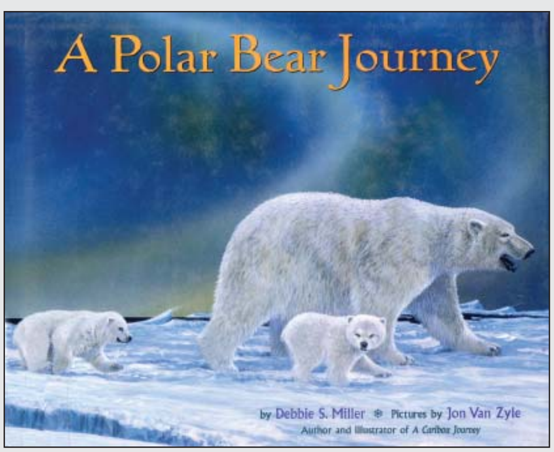
Tore and the Town on Thin Ice, by Carole Douglis (United Nations Environment Program, 2006), is available in print form or as a PDF which can be downloaded from the United Nations Publications page, at https://unp.un.org. A young boy in the Arctic is discouraged as he falls through the ice during a race. He is visited in his dreams by Sedna, Mother of the Sea, who counsels him to use his frustration and anger to motivate his actions. She sends him guides in the form of animals who tell how they are affected by the changing climate. Tore asks, "What can I do? I'm just a kid!" Sedna leads him to figure out ways in which he can help. Following the story are facts about the warming planet and simple, practical things that children can do to help. This book provides good information for children ages six through twelve.

Tree of Life: The World of the African Baobab, by Barbara Bash (Sierra Club Books, 1989), details the characteristics and role of the baobab tree. A multitude of animals feed off or depend upon the baobab for their own survival. This is another good book in examining the necessity for trees. A class reading this book might be inspired to create one like it for local trees such as the sugar maple, willow, palm, or spruce. The very specific role filled by the baobab in its ecosystem is outlined. Watercolor illustrations accompany this picture book resource for eight- through twelve-year-olds.

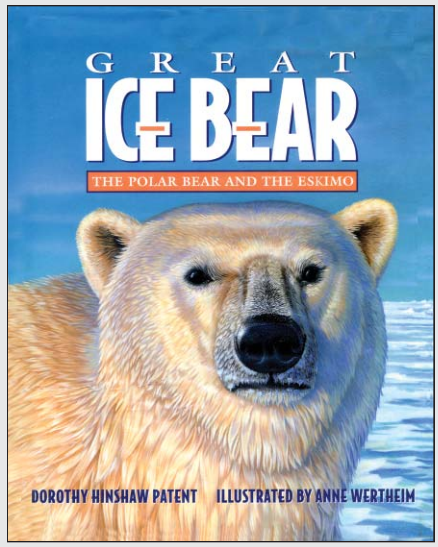


The People Who Hugged the Trees, adapted by Deborah Lee Rose (Roberts Rinehart Publishers,1990), is based on the legend of Rajasthani villagers who, nearly three centuries ago, protected trees from a Maharajah's quest for materials to build a new fortress. One girl recruits villagers to stop the soldiers sent to clear the forest. A pivotal moment occurs in the conflict between soldiers and villagers: a violent sandstorm erupts. When the Maharajah sees how his village has been saved by the stand of trees bordering the desert, he orders the soldiers to stand down. This book could accompany your class's tree-planting activities and helps to explain the benefits of trees.

A Polar Bear Journey, by Debbie S. Miller (Little, Brown and Company 1997), is a beautiful non-fiction picture book which follows a polar bear mother and two cubs through the first year of the cubs' lives. One of the remarkable things about this book is how it shows more than just a cuddly-looking bear. Scenes both relaxing and terrifying are portrayed as the bears' activities are described: sleeping, playing, hunting, learning to swim. Hazards such as breaking ice, pollution, and industrialization are briefly covered. Illustrations by Jon Van Zyle contribute to the stirring beauty of this excellent resource for six- to ten-year-olds. Miller and Van Zyle have created another book, *A Caribou Journey.*



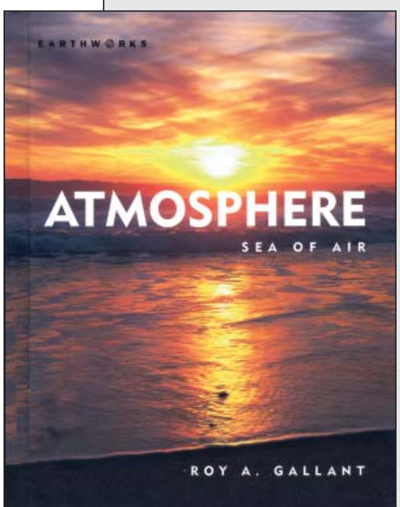
Great Ice Bear, by Dorothy Hinshaw Patent (Morrow Junior Books, 1999), is a great non-fiction book for older elementary students. The author searched for an animal to investigate and to write about the special relationship between humans and animals. She chose the polar bear and this text describes the life cycle, habitat, survival, and challenges of this great beast. Much attention is paid to northern native cultures, and ways in which they and polar bears have integrated over time. Exquisite paintings by Anne Wertheim accompany the text.



Loony Little, by Dianna Hutts Aston (Candlewicke Press, 2007), is an example of a children's book that tries very hard to address a topical concern through the mechanism of children's literature, but falls short of the mark. The illustrations by Kelly Murphy are lush and depict the arctic landscape with rich flowing colors. The text follows the predictability of the story of Chicken Little. The language and images seem to be directed to a young audience, but the message seems pretty inappropriate for this age (these animals will all die unless *you* do something). Even though it's tempting to offer this book to children because its subject is current and it is visually attractive, there are better options available to augment your study.

Resource Reviews

Atmosphere: Sea of Air, by Roy A. Gallant, is a great resource. This is a very easy-to-understand text written for older elementary students. In reviewing material before presenting to students, many teachers will also appreciate the simplicity with which basic concepts are explained, such as why the sky appears blue, what is an element (e.g., gold, neon), and why certain phenomena occur in different layers of our atmosphere. Some history of scientific thought is included. A chapter called, "Our Unclean Air" describes the greenhouse effect, pollutants, and possible future actions. "We have tremendous power. Whether we will use it to make the air cleaner remains to be seen."

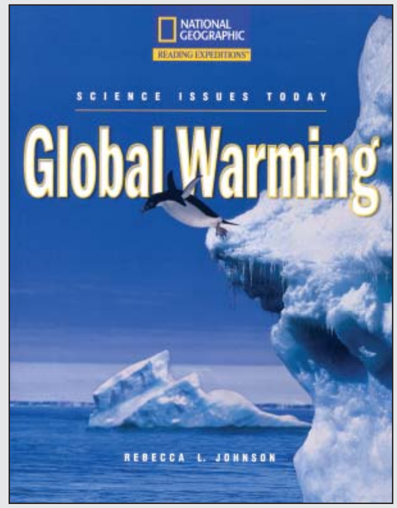


Atmosphere: Sea of Air. Benchmark Books, 2003. 80 pages. $32.79. Check with local libraries and bookstores.

Scholastic Atlas of Weather, by Donna Vekteris and Marie-Claude Ouellet, is a good introduction for older students to many aspects of weather and climates. Basic definitions of clouds, atmosphere, temperature, and how to measure these and other conditions, start the book. Descriptions of weather events such as tornadoes, snow, thunder and lightning, and forest fires make up the chapter entitled, "When Weather Runs Wild." Other influences on weather are discussed, and how meteorologists make predictions is included. Several fun activities follow the text, along with a glossary, list of resources, and other weather facts.

Scholastic Atlas of Weather. Scholastic, 2004. 80 pages. $17.95. 800-724-6527. https://www.shop.scholastic.com.

Science Issues Today: Global Warming, by Rebecca L. Johnson, is one of National Geographic's Reading Expeditions. This small paperback booklet concisely describes with



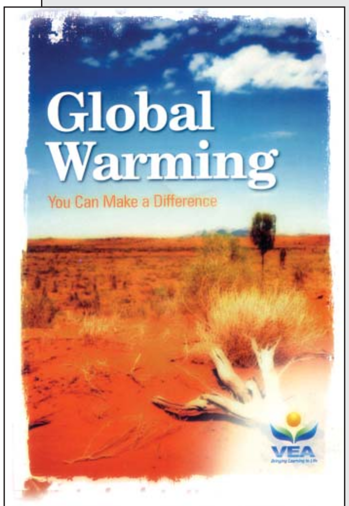
age-appropriate clarity the greenhouse effect, greenhouse gases, potential causes for warming, and possible actions. Important points are illustrated with crisp photographs and simple captions. Bulleted lists summarize ideas presented in the text. This is a great resource for eight-to-thirteen-year-olds. The last section of the book focuses on how to write persuasive letters (to the local paper, to representatives), and shows two students going through the process. Web sites and a glossary are also included.

Science Issues Today: Global Warming. National Geographic Society, 2002. 32 pages. Books sold in 6-pack for $44.95. 800-368-2728. http://ngschoolpub.org.

Global Warming, by Alvin and Virginia Silverstein and Laura Silverstein Nunn, is an informational text appropriate for mid- to older-elementary students. With chapters that examine questions such as, "Is Global Warming for Real?" and, "Can Global Warming Be Stopped?" this book describes some of the controversy surrounding this and other science topics, and includes more than one perspective. This book would be useful to students who are researching the topic.

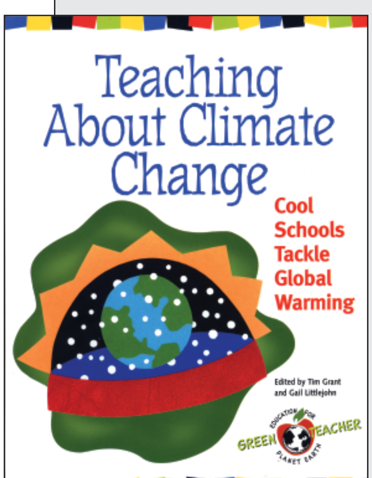
Global Warming. Twenty-First Century Books, 2001. 64 pages. $19.95. 800-328-4929. http://www.lernerbooks.com.

The ***Greenhouse Effect*** and ***Global Warming: You Can Make a Difference*** are two Australian-made videos for middle school students. ***The Greenhouse Effect*** explains greenhouse gases and their effects. It includes extra materials on ice core testing and formulas. ***Global Warming*** explores possible factors and actions, on both international and individual levels. Both are very clear and well organized and offer many discussion points for students.



The ***Greenhouse Effect*** and ***Global Warming: You Can Make a Difference***. VEA, 2007, 2006. Each about 25 minutes. $89.95 each. 866-727-0840. http://www.veavideo.com.

Teaching About Climate Change: Cool Schools Tackle Global Warming, edited by Tim Grant and Gail Littlejohn, is a collection of some of the best articles on the topic from *Green Teacher* magazine (which is also an excellent resource). Twenty-five articles on foundational concepts, energy and transportation alternatives, home and community, and the school building are included with a list of organizations and resources and a curriculum index. All age levels are addressed in teacher-written articles based on classroom experiences. Many examples of direct action are presented in this excellent resource.



Teaching About Climate Change: Cool Schools Tackle Global Warming. New Society Publishers, 2001. 74 pages. $12.95. 888-804-1486. http://www.greenteacher.com.

http://www.amnh.org: The American Museum of Natural History's site has information on their "Seminars in Science" program. Teachers can take their courses online (graduate credit available) for $445. Topics include *Earth: Inside and Out*, which looks at how the earth evolved and the causes of climate and climate change.

The Discovery of Global Warming, by Spencer R. Weart, offers a historical overview of the science and politics of climate research. If you have the time, this might offer some valuable perspective on the whole subject. This will not necessarily make it easier for you to walk into class Monday morning and teach a lesson, but it will increase your knowledge and therefore your confidence in talking about the issue with students, administrators, and parents. Seventh- and eighth-grade students could read excerpts and discuss or debate the points raised there. This is a highly readable text.

The Discovery of Global Warming. Harvard University Press, 2003. 229 pages. $15.50. 800-405-1619. http://www.hup.harvard.edu.

http://www.loe.org: *Living on Earth* with Steve Curwood is broadcast on National Public Radio. Its Web site has transcripts, podcasts, and additional materials on topics such as the coal industry, how communities around the world are affected by changing climate, and Wangai Maathai, the Nobel Prize winner for her Green Belt tree-planting movement in Kenya.

http://www.windos.ucar.edu/citizen_science/budburst: Project Budburst is a phenological network field campaign, studying when plants and flowers bloom. Using data submitted by students, scientists learn about the prevailing climatic characteristics of a region over time.

http://www.citizens4change.org: under the Global Education page, you can find a collection of links grouped by appropriateness for kids, volunteers, and teachers.

http://www.davidsuzuki.org/kids: Nature Challenge for Kids is David Suzuki's site emphasizing individual ecological actions. Lots of links to resources.

Striving for Simplicity

Teaching Science with The Climate Project

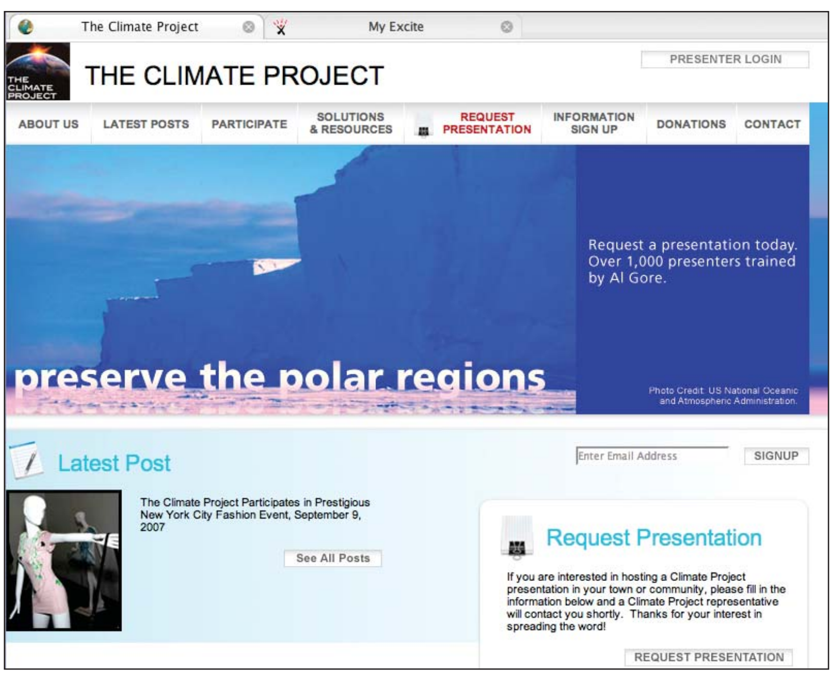
by Paulina Essunger

We asked Paulina Essunger to write this story about her experience as a volunteer with The Climate Project because she brings her own multi-faceted perspective as a science editor to this topic. As the parent of a first-grader, she has personal reasons to think deeply about long-term changes in our environment and how those may affect the lives of our students. —Editor

My first teaching experience—substitute teaching in a second-grade classroom—left a lot to be desired. I had no relevant skills whatsoever, really. Halfway through the day, the kids, sweetly, asked if we might sing some songs. "Sure," I said, pleased for them to take this initiative. They chose the song, and I innocently smiled and tried to hum along: ". . . thank you for today; we'll see you tomorrow!" and with that they all made a mad dash for the door.

This was, as it turned out, their end-of-the-day-song; it created its own kind of snowball effect. Once they reached a certain point in the song, nothing really could have stopped them from stampeding toward the door for an extra recess for them and a good lesson for me. At least they didn't leave the school and go home.

Now, some years later, as a volunteer with The Climate Project, I have been presenting modified versions of the slide show featured in the film documentary, *An Inconvenient Truth*, to local audiences, including college and high school students and several eighth-grade classes. Last winter I accepted an invitation to speak to what I understood was a class of eighth graders. Too late, I learned it was fifth grade. I didn't really think *An Inconvenient Truth* was appropriate for fifth graders. These students would be my youngest yet. I had a flashback to the kids storming out of the classroom. I felt as inadequately prepared for this gig as I had been for filling in, in that second-grade classroom.



The Climate Project

The Project is made up of more than 1,000 volunteers whose training includes briefings on the scientific background behind the film. The Project provides an energizing network, and our discussions have repeatedly focused on the question of discussing climate change with, and teaching it to, "younger" children—and which slides or topics are appropriate for which age groups. Many volunteers are K–8 teachers themselves; their experience helps shape these discussions.

The film ends with suggestions for what we can all do to help mitigate climate change—the suggestions roll by to the tune of Melissa Etheridge's, "I Need to Wake Up." But many Climate Project audiences want a much greater focus on direct actions: What they can do, what they should do. Consequently, in tailoring our presentations, many of us spend a lot of time on solutions. Interestingly, public opinion research suggests that understanding that we have real opportunities to *solve* the problem of human-made climate change improves the odds of our understanding the problem itself.

Because the problem requires a major transformation of our energy system, it will require political solutions and new policy measures. This means people in general will have to take more responsibility for their contributions to democracy, becoming the informed public on which democracy is based.

"Tuck" the stuffed owl, an elementary school mascot, traveled with climate scientists to Antarctica. Here, Tuck is hanging out in a snow pit scientists use to study the annual layering of snow (the darker bands are made up of the more compacted winter snow; the lighter bands are made up of the coarser summer snow).

In the classroom

While I think fifth graders have a responsibility to do their part toward supporting this feature of democracy, I do not think it's by their seeing the connection between policy solutions and their own actions. Nor is it by calculating their carbon footprints, although that can be a fun and, if done with care, edifying classroom activity. Happily, I instead think most fifth-graders' job is to try science on for size.

Many fifth graders will use their still-vivid imaginations as we talk about drilling and extracting mile-long vertical cylinders of ice, "ice cores," that spell out the earth's climate history, in detail, up to one million years back in time. If it's winter, and snow is available, let them think about the ice cores as we scoop up the snow, pressing it together harder and harder. No matter how tightly they compress the snow crystals, tiny pockets of air are trapped between the crystals inside the snowball, too.

As snow falls, the flakes land to make a fluffy softness. The soft feeling is largely the result of the air trapped between the flakes. As more snow falls on top, the bottom snow gets packed tighter; it gets less soft, but some air remains in there, and when the snow finally turns to ice—a process we can approximate by pressing the snow with our hands and shaping snow balls—some air is still trapped inside, sealed off in little bubbles.

Drilling down into this ice, for example on the Antarctic ice sheet, the air bubbles provide an extended history of Earth's atmosphere. One eighth-grade student succinctly captured the enormity of the fact that these frozen bubbles provide us with access to air along a timeline of almost a million years: "Ewww! Talk about stale air!" Following the girl's comment, discussion in that class focused on: "What is "stale" air, anyway? What is *air*, again? Would the air in the old ice be stale? Why?"

These seemed to be valuable questions to explore with the fifth graders, too. If you could melt some very old ice, "What would it taste like? Why? What in that ice could possibly tell us anything about how hot or cold or wet or dry it was back when the water evaporated, then made the clouds, that brought the snow, that fell and formed the ice?"

A good slide show presentation—for any age group—amounts to telling a well-illustrated, dramatic story. No matter the age of my audience, when explaining how glacial ice keeps its own record of time through a layering phenomenon, I narrate and act out the following:

Imagine you are in Antarctica. You dig two big pits next to each other—so that there is a thin wall between them. Now, jump down into one of them, cover the top of it with a tarp and face the shared wall. Sunlight will come through the wall, and you will see layers of light and dark snow. The light snow is letting more light

NO SNOW?

I know teachers who have great luck with ice chips (as stand-ins for snow) for students to mess around with, for them to squeeze and realize there's air trapped in there. So I decided to include the ice chips again, even though the main lesson I had learned from ice chips so far was that they melt very fast indoors. (I think you might need access to a *lot* of crushed ice, and have the students all working together on a table with a big pile of ice.)

Paulina Essunger lives with her family in Vermont. She telecommutes as a science editor specializing in climate change. When she is not volunteering with The Climate Project she enjoys helping out at her son's elementary school.

through because it is coarser. That's the less tightly-packed summer snow. The darker layer is finer-grained winter snow.

In telling this, I go through the motions of digging the pits, jumping in, squinting at the brighter layers, and more. As I "jump in," I switch slides from one showing scientists on the glacier to one showing the view from inside the covered pit. For a great example, see: http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=17131.

The Climate Project has grown out of the explanatory power of images such as these, which are readily available to schools through search engines that provide image search tools. It may be that we could all do more with images. I'm not suggesting classes be turned into yet more "screen time," but teachers may want to further explore this medium. Options include using images as backdrop illustrations to a lesson or discussion, with the aid of a laptop, screen, projector, and preferably, a remote control to enable a more natural discussion and story-telling atmosphere.

Back to the snow pits

"The seasonal layering effect is retained even as the snow is compressed to ice—the different qualities of snow yield different qualities of ice; you can count the layers of snow or ice, much like rings on a tree, and determine, for instance, how many years apart two given layers are. What happens to a layer of ice as even more ice accumulates on top of it, and more and more ice? Does it keep getting pressed together? Does the layer get thinner? How much can it get pressed together? Then what happens?"

For my fifth-grade group, the goal was to generate and explore questions like these. This required a conceptual shift: "Ask not what to take out of the slide show for the fifth graders but what to leave in." I chose to focus on the message about climate and our atmosphere that can be deciphered from the ice cores. In retrospect, this decision seems obvious. Not necessarily the ice part, but choosing one of the most basic science components and having as much fun with it as I knew how.

For simplicity

In reflecting on working with students this age I'm tempted to simplify even more, choosing *either* air bubbles (and their record of CO_2) or the ice (and its record of temperature and precipitation). But, of course, they go together and have a joint story.

Next time the weather is right, I can't think of a better way to end a class on the secrets of ice cores than by making a mad dash for the door—having that extra recess—and catching a moment in time, in the history of our atmosphere—if only for a moment—in a simple snowball.

The Ethics and Efficacy of Teaching Climate Change

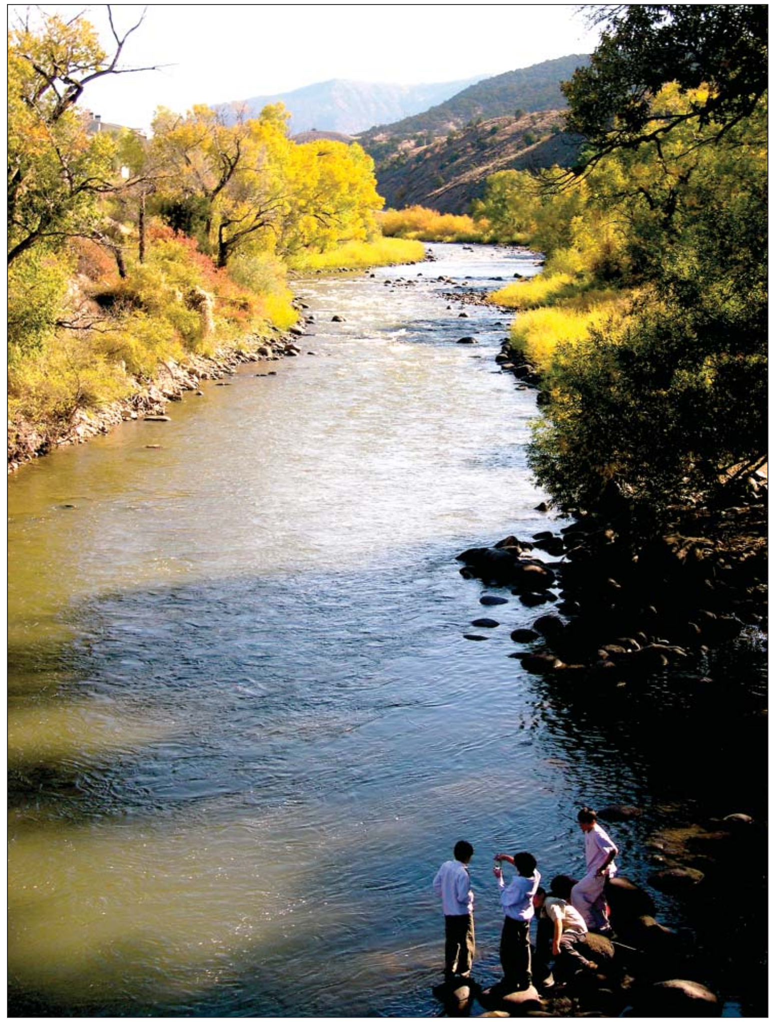
by Ted James

If we are to teach adolescents about the threats of our changing climate we should also empower them to feel that they can make a difference. Middle school science teachers face ethical dilemmas when it comes to teaching about global warming. To not share the latest scientific findings on climate change would seem a gross error of omission, comparable to 16^{th} century teachers not mentioning that the world is round.

As often happens with scientific discoveries, current knowledge can leap ahead of the typical understanding of the community, especially if people are not actively trying to educate themselves on a topic. Teachers of climate change will likely find themselves paddling upstream as public knowledge lags behind the most current scientific consensus. Adding to that burden are textbooks such as mine that state specifically, "Not everyone agrees about the causes of global warming. Some scientists think that the 0.5 Celsius degree rise in global temperatures over the past 120 years may be part of natural variations in climate rather than a result of increases in carbon dioxide." This particular printed textbook statement is now out of date, but in the hands of a parent can be a potent tool to push against this teaching.

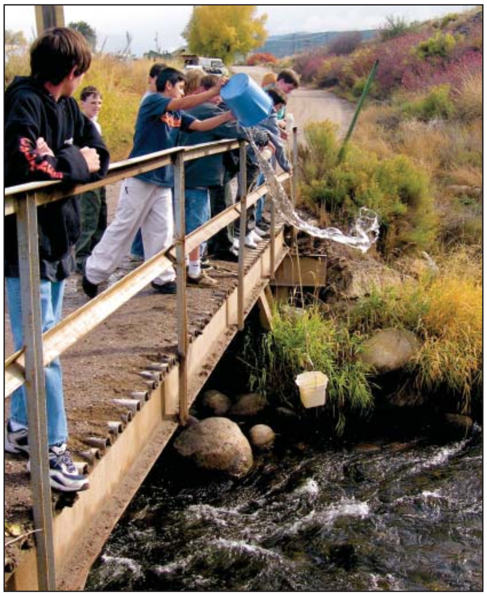
Even more importantly, constructing deep understandings of the mechanisms and ramifications of climate change may leave students depressed and turned off to science if they are not also provided with opportunities to take some action. At Eagle Valley Middle School, students are provided an opportunity to take action through a class called River Watch.

John Muir wrote over a hundred years ago, "When you look at anything in the Universe you find that it is hitched to everything else." As a middle school science teacher in Colorado, I am charged with teaching to the following academic standard, "I will understand the structure and function of living things, the processes of life and how living things interact with each other and their environment." Teaching students about the ecological consequences of climate change can provide numerous opportunities to address the various aspects of this global standard. To some, the teaching of climate change may seem a burden, one more concept or unit to fit into an already overwhelmed curriculum. However, I have found that it can be readily incorporated into existing curriculum.



Climate studies

Seventh graders at my school begin the year studying weather and climate. They learn the difference between weather and climate and gain the background knowledge that will help them understand climates around the world. Later in the year when introduced to concepts in biology and ecology they gain an apprecia-



tion for Earth's various biomes and how a biome is largely defined by the temperatures and precipitation patterns that characterize its climate. They learn how the plants in a biome are uniquely adapted to the climate in that region and how the other organisms depend on the plants to pass energy up the food chain. If the temperature and precipitation patterns change, the plants have to adapt or they will die off.

If they die, everything up the food web is affected and must also adapt, or die. As plant communities die off, new ones that can survive the new climate may move in if the soils haven't been eroded away from the lack of vegetation. The new plant communities become the foundation for the new biome. This is a simplistic view but one that a seventh grader can understand and remember.

For many students, truly grasping this concept and then looking at the recent data, and conclusions issued by the Intergovernmental Panel on Climate Change in their 2007 report, can lead to disillusionment because of the dire predictions the evidence offers. It is important to energize and empower these teenagers with Service Learning opportunities so they can feel that they make a difference and there is indeed hope for their future.

"My biggest concern about climate change is having all the glaciers melting, causing the sea level to rise which will eventually put coastal areas under water."
—MEGAN, 8TH GRADER.

"My biggest concern about climate change is how the animals will survive, and if the West will get even hotter. Will we still be able to live here? I am also worried about the health of our rivers."
—ZOE, 8TH GRADER

Service learning and River Watch

My favorite part of being a teacher at Eagle Valley Middle School is getting to lead the River Watch program. I am energized by the students' enthusiasm. I am typically confronted by eager students asking, "Mr. James, Mr. James! Do we get to go to the river today?" On the other hand, I must say that after a lesson involving a video or reading an article about climate change I can sense the energy being zapped from my students. The mood of the classroom is palpably different. Students often leave with a depressed demeanor. As a teacher, I find this difficult to take. Without the service learning to balance this negative energy, I can understand why many educators may choose to steer clear of even teaching about climate change. Depressed teenagers are no fun to be around.

The endangered razorback

This past school year EVMS students made a very unique contribution to our watershed by raising endangered razorback suckerfish in our classroom aquarium. It was a special program with the U.S. Fish and Wildlife Service and the Colorado Division of Wildlife that was offered to five select schools in Colorado. This successful program provided a myriad of real-world learning experiences, including lessons on how human influences can be detrimental to animal habitats.

A decade or so earlier, the razorback population (an endemic species in the Colorado River) had been reduced to less than a dozen fish in its natural habitat between Rifle, Colorado and Lake Powell in Utah. Historically these fish, which can grow to four feet in length, had large populations and were referenced in the oral histories of both Native Americans and pioneers in the Colorado River Watershed. Scientists were able to convince the U.S. Senate to appropriate a million dollars to the recovery program. They showed the politicians how razorbacks are indicators of water quality in this river which supports a huge human population in the Western United States. It had been determined that the razorback population had declined because of human activities such as dams and impoundments along the river, as well as low flows brought on by extended droughts linked to climate changes.

In September of 2006, EVMS seventh graders were provided with six baby razorbacks who were descendants of this original population to raise. While learning the principles of ecology, students fed their razorbacks daily and maintained a healthy habitat for these cute little critters. They applied their skills gained from River Watch class.

They did the same experiments to test the aquarium as they used to monitor the chemistry of their four local stream sites. At the end of the school year they measured and tagged their fish and released them into the Colorado River. What a celebration it was!

Eagle Valley Middle School has had a River Watch program for eleven years. They are one of nearly a hundred schools in the Colorado Watershed Network that are monitoring the ability of their local streams to tolerate pollution. Students are often taken aback when they learn that in the United States it is legal to pollute rivers. There are regulations that set minimum standards for water quality based on each stream's unique chemistry and tolerance levels. Students in the network have collected much of the data used by the State's Water Commissioners to set the standards. The Colorado Watershed Network has provided more data on water quality than all of the rest of the western State's efforts combined.

This year the EVMS River Watch program is expanding, offering students an opportunity to continue their study of rivers in eighth grade. The eighth-grade River Watch class focuses on the effects of climate change on rivers. Not only do the eighth graders continue monitoring their stream sites, they also serve as teaching assistants to bring the new seventh-grade River Watchers up to speed.

Students test their rivers for hardness, alkalinity, pH, dissolved oxygen, and temperature levels as well as sending samples to the CWN lab in Fort Collins to monitor for heavy metals and nutrient pollution. Additional service learning opportunities are provided each spring, when as seventh graders, these same students participate in an aquatic research program led by the local Gore Range Natural Science School. There they hone college-level biology research skills by sampling and analyzing the macroinvertebrate populations which are indicators of water quality in their streams. EVMS students have been collecting this data for a decade now and it is available to scientists with the Colorado Division of Wildlife and the U.S. Bureau of Land Management.

Realizing that the overall amount of fresh water available on the planet is likely to decrease due to our changing climate and burgeoning human population can be discouraging, but at least these students are actively involved in a network that seeks to protect and enhance their water resources. Obviously time will tell how dramatic and pervasive these changes will be. While learning about science, these students are watching rivers and developing some ethics of their own.

Coding a pit tag

"I like River Watch because I get to learn outdoors. I can think better when I am outdoors".
—JOSH, 8TH GRADER

"River Watch is important because it gives us a chance to monitor the river. If we watch it over a period of time we can see a pattern. If someone pollutes the river, we can see a change, plus we have data to prove that it was not polluted before."
—ZOE, 8TH GRADER

Resources

DVDS

Strange Days on Planet Earth: The One Degree Factor. Directed by Mark Shelley. National Geographic, 2005.

Global Warming: The Signs and the Science. PBS Home Video, 2005.

"Global Warning." *60 Minutes* TV News Program. Scott Pelley, Correspondent. CBS Broadcasting, aired February 19, 2006.

TEXTBOOK

Prentice Hall Science Explorer Series: *Weather and Climate.* New Jersey: Prentice Hall, 2002.

WEB SITE

Teachers' Guide to High Quality Educational Materials on Climate Change and Global Warming, Susan Joy Hassol, http://www.hdgc.epp.cmu.edu/teachersguide/teachersguide.htm, 2002.

Ted James is in his twelfth year of teaching science to seventh graders at Eagle Valley Middle School in Eagle, Colorado. He is on the Board of Directors of both the Colorado Watershed Network and the Gore Range Natural Science School.

What's a Kid to Do?

It seems sometimes like changes in the climate are huge and distant phenomena impacted more by big business and industry than by individuals. But there are indeed some simple things that students have been doing throughout the nation to impact the level of CO_2 in our atmosphere. Here are just a few:

1) Getting to school: Fourth graders at the Friends Meeting School in Ijamsville, Maryland, checked motorists' tire pressure to ensure the most fuel efficient travel possible. Walking, biking, and taking the bus to school (rather than driving a car) all save on carbon emissions. http://www.walkingschoolbus.org.

2) Reading, writing, and paper consumption: Change the Margins! (http://www.changethemargins.com.) By resetting the default margins on word processors, students have used less paper over time, which means fewer trees cut, and less manufacturing of paper. Using scrap paper, collecting paper to recycle, and using both sides of a sheet of paper also reduce consumption.

3) Time to eat: Students are reusing containers, choosing products sold in less packaging, and growing their own food in school gardens. Glenview Elementary students in Oakland, California, have even made solar ovens to cook snacks and lunches.

Students at Columbia School for Girls in Columbus, Ohio, deliver their tree donation to the community park.

4) On the playground: Elementary students in Brewerytown, Pennsylvania, participated in a tree-planting program. Tree-planting is a great activity that enhances the ecosystem, provides shade, and consumes some of that infamous carbon dioxide we're trying to get rid of. This can also be a great way to involve the community with the school.

5) At the end of the day: Schools are turning off appliances, lights and computers (even at the power source, as some equipment draws electricity when switched off, but plugged in). Fourth-grade students in Jasper Elementary school in Alberta, Canada, have done home energy audits to better understand ways to reduce energy needs.

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